Standard C-2: Students will demonstrate an understanding of atomic structure and nuclear processes.

Content Support Websites

Chemistry Coach
http://www.chemistrycoach.com
High school web site that provides information on all aspects of chemistry. It also has links to other sites .
Deals with all of standard C-2

Periodic Trends
http://chemistry.about.com/library/weekly/aa071802a.htm
Presentation on Periodic Table and its characteristics. This site was developed by two high school chemistry teachers.
C-2.3

Orbital Notation
http://id.mind.net/~nmhschem/QMNotes.htm
Review of Quantum Mechanics. It includes rules for describing electron arrangement.
C-2.1

Electron Affinity
www.webelements.com/webelements/properties/text/definitions/electron-affinity.html
This site explains what electron affinity is and looks at the factors that affect its size.
C-2.2, C-2.3

Ionization Energy
www.shodor,org/chemviz/ionization/students/background.html
This site provides a good description of ionization energy and how it relates to the Periodic Table. Good graphics are provided.
C-2.2 and C.2.3

Fusion and Fission
www.focusfusion.org
This site provides a detailed comparison between fusion and fission. It also provides links to other sites dealing with these two chemical reactions.
C-2.4

Carbon Dating
http://science.howstuffworks.com/carbon-14.htm
This site introduces carbon dating and how it works. It also enables students to see how carbon-14 is made and how it is used to date the age of a fossil.
C-2.5 and C-2.7

Alpha, Beta and Gamma Rays
http://en.wikipedia.org/wiki/Gamma_rays
Several ideas concerning nuclear reactions are presented at this site. These include descriptions of alpha, beta and gamma rays. Information on half-life and carbon dating are also presented at this site.
C-2.5 and C-2.6

E=mc2
www.aip.org/history/einstein.enc1/htm
This site provides a historical background to Einstein and his development of the world's most famous formula C-2.9

Suggested Literature

Asimov, Isaac; Building Blocks of the Universe, Abelard-Schuman, Ltd. 1997
ISBN:0200710990
This book provides a brief discussion of 105 chemical elements detailing structure, forms and uses.
C-2.1

Silverman, Ken; The Radioactive Boy Scout: The Freightening True Story of a Whiz Kid and His Homemade Nuclear Reactor. Villard. 2005
IBSN:0812966600
This is the true story of a Boy Scout who built a crude nuclear reactor in his backyard and his troubles with the Federal Government,.
C-2.4

Housecroft, Catherine E.; Inorganic Chemistry. Person Prentice Hall. 2004
ISBN: 0131399268
A textbook dealing with all facets of inorganic chemistry. In-depth description of atoms, the Periodic Table and atomic trends (including electron configuration, ionization energy, electron affinity, atomic size and ionize size).
C-2.2, C-2.3

Peat, I. David; Cold Fusion: The Making of a Scientific Controversy. Contemporary Books. 1990.
ISBN: 0809240858
This book presents the history of cold fusion including the political and social impact of energy technology development.
C-2.4

Szasz, Ferene Morton; The Day the Sun Rose Twice: The Story of the Trinity Site Nuclear Explosion. University of New Mexico Press. 1995.
ISBN: 082630768X
This book describes the scientific processes that led to the detonation of the first atomic bomb. It presents not only the scientific and historical background, but also the political fall out world wide for the United States.
C-2.4, C-2.5, C-2.8, and C-2.9

Bodanis, David; E=mc2: A Biography of the World's Most Famous Equation. Pan MacMillan. 2005.
IBSN: 0330391658
Historical background to the formation of the famous equation. It also goes into the relationship with the Manhattan Project.
C-2.9

Cotton,F. Albert, Wilkinson, Geoffrey and Gause, Paul L.; Basic Inorganic Chemistry. John Wiley &Sons.1994.
ISBN: 0471505323
This book has sections which deal with atomic orbital, electronegativity and new approaches to the depiction of ionic structure.
C-2.1

Winter, Mark S.; Foundations of Inorganic Chemistry. Oxford University Press. 2001.
ISBN: 0198792883
Sections of this textbook describes s, p and d block elements.
C-2.1

Suggested Streamline Video Resources

Elements of Chemistry: The Building Blocks of Matter
ETV Streamline SC
Students explore the structure of atoms, isotopes and ions. The basic ideas of the Quantum Theory are introduced.
The entire video is 20 minutes in length.
C-2.1 and C-2.2

Elements of Chemistry: The Periodic Table
ETV Streamline SC
The Periodic Table is explained. This includes the placement of the elements on the table and an explanation of the contents of the squares on the table.
C-2.3

Simple Science: Discovering the Elements.
ETV Streamline SC
Quick review of the background to the Periodic Table. It shows how the elements are organized in the table and a historical background as to the reasons Mendeleev set up the table as he did. C-2.3

Chemistry Connections: Nuclear Changes
ETV Streamline SC
This video traces the discovery of radioactivity on to the development of the fission bomb. It also explains the conversion of mass to energy using Einstein's equation.
C-2.4 and C-2.9

Careers in Chemistry

Nuclear Technician
These workers operate nuclear research equipment, monitor radiation and assist nuclear engineers and physicists in research. An associate degree is required for this career.
C-2.4, C-2.5, C-2.8

Chemical Engineer
Persons in this field apply the principles of chemistry and engineering to solve problems involving the production and use of chemicals. They build a bridge between science and manufacturing. A BS degree in Chemical Engineering is necessary for this occupation
C-2.1 through C-2.9

Radiologic Technologist
These individuals take x-rays and administer radioactive materials to patients for diagnostic purposes. Some specialize in computerized topography and magnetic resonance imaging. An associate degree is necessary for this occupation.
C-2.5

Chemical Technician
Individuals who chose this field conduct chemical and physical qualitative and quantitative analysis of solids, liquids and gaseous materials for purposes such as research and development of new products.
C-2.1 through-2.3

Pharmacy Technician
These individuals prepare medications under the direction of a pharmacist. They may measure, mix, count out, label and record amounts and dosages of medications. An associate degree is required.
C-2.1 through C-2.3

C-2.1 Illustrate electron configurations by using orbital notation for representative elements

Revised Taxonomy Level 2.2-B <u>Exemplify</u> (<u>illustrate</u>) conceptual knowledge

In Physical Science, Students

- Compare the subatomic particles (protons, neutrons, and electrons) on an atom with regard to mass, location, and charge, and explain how these particles affect the properties of an atom (including identity, mass, volume, and reactivity). (PS-2.1)
  - The electron cloud is the space where electrons are moving erratically in regions of space called energy levels
    - Energy levels are regions of space at increasing distances from the nucleus
    - There is a maximum number of electrons that can occupy each energy level and that number increases the further the energy level is from the nucleus

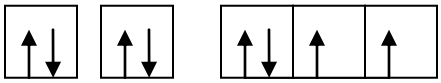
  (Students did not address quantum numbers in physical science)
- Explain the trends of the periodic table based on the elements' valence electrons and atomic numbers. (PS-2.3)
  - Determine how many energy levels are occupied in a given element by recognizing that the period in which an element appears on the periodic table indicates the number of occupied energy levels.
  - Determine the number of valence electrons for selected groups of elements (groups 1,2,13,14,15,16,17,18) when given the element's group number or name (Students have not been introduced to electron orbital notation)

It is essential for students to

- Understand that the representative elements are those elements within the first two groups (groups I and II on the far left) and the last six groups on the right of the Periodic Table.
- Understand the first two quantum numbers and use them to describe the location of electrons in representative elements in the ground state
  - Principle quantum number
    - Understand the aspect of electron location described by the principle quantum number. (Energy level)
    - Understand that the principle quantum number is designated by numbers 1 through 6 and understand the meaning of each of those numbers in reference to the location of the electron.
  - Orbital quantum number
    - Understand the aspect of electron location described by the orbital quantum number. (Type of orbital)
    - Understand that the orbital quantum number is designated by one of four letters (s,p,d,f) and understand the meaning of each of those letters in reference to the location of the electron
    - Understand how many of each type of orbital are possible in each of the 6 energy levels.
    - Understand that two electrons can occupy each orbital

- Use standard orbital notation to illustrate the electron configuration of a representative element in the first three periods based on the element's position on the periodic table.

Orbital Notation for Oxygen:



  - Additional methods of illustrating electron configuration include
    - Electron configuration notation
      For oxygen: $1s^2 2s^2 2p^4$

    - Electron Dot notation (to show valence electrons)
      Electron Dot Notation or Selenium:

      : Se :

Tradition Chemistry differentiation

- Understand the last two quantum numbers and use them to describe the location of electrons in representative elements in the ground state
  - Magnetic quantum number
    - Understand what aspect of electron location this describes.
    - Understand that it is designated by one of 7 numbers and understand what each of those numbers mean in reference to the location of the electron.
  - Spin quantum number
    - Understand what aspect of electron location this describes.
    - Understand that it is designated by numbers a positive (+) or a negative (-)
    - Understand that two electrons occupying the same orbital must have opposite spins
  - Understand that no two electrons in an atom can the same set of quantum numbers
- Illustrate the electron configuration for all elements on the periodic table,
  - Understand that the order in which electrons fill orbitals reflect the most stable electron arrangement for the given number of electrons.
    - Students should be able to make general statements concerning stable electron arrangements
      - All "d" orbitals are less stable than the "s" orbitals in the next-highest energy level
      - All "f" orbitals are less stable than the "s" and the "p" orbitals which are two energy levels higher, and less stable than the "d" orbitals which are one energy level higher
- Understand exceptions to the normal orbital filling order (Cr, Mo, Cu, Ag, Au)
  - What the exceptions are

- Why they are exceptions

❖ Use a Bohr model of the atom to explain the bright line spectrum in terms of electrons moving between energy levels

Assessment

The verb exemplify (illustrate) means to find a specific example or illustration of a concept or principle, therefore the major focus of assessment will be for students to give examples that show that they understand stable electron arrangement of representative elements in the ground state. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together. In this case, that students understand the characteristics of the quantum numbers and can use those characteristics to predict the stable electron arrangement of elements. Because students must demonstrate conceptual knowledge, assessments should require that students justify why their examples meet the above criteria.

C-2.2 Summarize atomic properties (including electron configuration, ionization energy, electron affinity, atomic size, and ionic size).

Revised Taxonomy Level 2.4 <u>Summarize</u> conceptual knowledge

In Physical Science students

- Predict the charge that a representative element will acquire according to the arrangement of electrons in its outer energy level.(PS-2.5)

It is essential for all students to

- Understand the following atomic characteristics and properties (in terms of atomic structure) and understand what variables influence the magnitude of the characteristics or properties for a given element.
  - Electron configuration
  - Ionization energy
  - Electron Affinity
  - Relative size of atoms
  - Ionic size

Tradition Chemistry differentiation

- Understand electronegativity

Assessment

The revised taxonomy verb, summarize means "to abstract a general theme or major point" For this indicator, the major focus of assessment should be to insure that students have a deep conceptual understanding (in terms of atomic structure) of the terms electron configuration, ionization energy, electron affinity, and atomic radius, and ionic radius. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together. In this case, that students understand how atomic structure determines the characteristics and also how the characteristics influence each other, (for example, how atomic size influences reactivity).

C-2.3 Summarize the periodic table's property trends (including electron configuration, ionization energy, electron affinity, atomic size, ionic size, and reactivity).

Revised Taxonomy Level 2.4 <u>Summarize</u> conceptual knowledge

In Physical Science students

- Become familiar with the periodic table in terms of
  - Locating periods and groups
  - Locating metals, metalloids, and nonmetals
  - Locating and listing referenced elements when prompted with a period number or group number
  - Determining a given element's atomic number.
  - Determining the number of electrons that an atom of a given element contains.
  - Determining how many energy levels are occupied in a given element by recognizing that the period in which an element appears on the table indicates the number of occupied energy levels.
  - Determining the number of valence electrons.
- Explain the trends of the periodic table based on the elements' valence electrons (PS-2.3)
  - Valence electrons across a period. (1-3 only)
  - Valence electrons top to bottom within a group.
  - Energy levels across a period.
  - Energy levels from top to bottom within a group.

It is essential for all students to

- Identify the chemical and physical properties off elements according to their location on the periodic table.
- Understand the structure of the periodic table and be able to explain the properties on which it is based and its unique shape..
- Understand how the value of atomic characteristics and property trends vary from element to element across and from top to bottom on the periodic table
  - Including
    - Electron configuration
    - Ionization energy
    - Electron Affinity
    - Atomic radius
    - Ionic radius
    - Reactivity
  - Be able to describe each trend in terms of how the value changes across a given period and from top to bottom in a given group.
  - Understand why the trend occurs (according to atomic structure and periodic table arrangement).
  - Be able to predict relative values (greater or smaller) for each of the characteristics or properties for a given set of elements based on their positions on the periodic table.

Tradition Chemistry differentiation

- Understand the trend of electronegativity values on the periodic table

Assessment

The revised taxonomy verb, summarize means "to abstract a general theme or major point" For this indicator, the major focus of assessment should be to insure that students have a conceptual understanding of how the periodic table is arranged so that it can be used to infer the characteristics and properties of elements. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together. In this case students understand how the periodic table is used as a tool for chemistry

C-2.4 Compare the nuclear reactions of fission and fusion to chemical reactions (including the parts of the atom involved and the relative amounts of energy released).

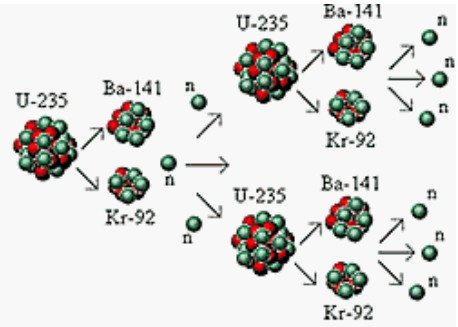
Revised Taxonomy Level 2.6 <u>Compare</u> conceptual knowledge

In Physical Science students:

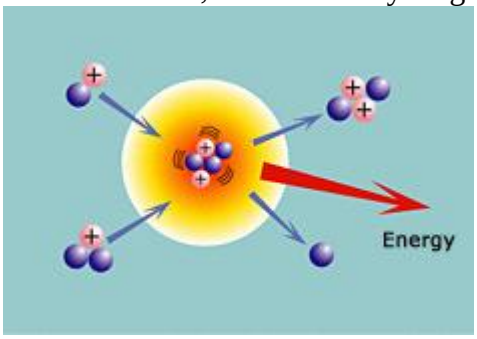
- Compare fission to fusion (including the basic processes and the fact that both fission and fusion convert a fraction of the mass of interacting particles into energy and release a great amount of energy. (PS-2.6)

It is essential for the students to

- Understand that chemical reactions occur in the electron clouds of atoms and nuclear reactions involve the nuclei of atoms.
- Illustrate the process of nuclear fission either in words or with a diagram



- Understand that there are several possible reactions that may occur during a fission reaction.
- Illustrate the process of nuclear fusion, in words or by diagram



- Understand that there are many possible reactions that may occur during a fusion reaction.
- Understand the source of energy from a nuclear reaction in terms of the nuclear mass equivalent, (mass defect) and Einstein's equation, $E = mc^2$
  - For energy release in fusion or fission, the products need to have a higher binding energy per nucleon (proton or neutron) than the reactants.
- Understand that the energy that results from a chemical reaction is the energy associated with chemical bonds (involving the electrons of the atom).

- Differentiate the energy from fusion reactions, fission reactions, and chemical reactions in terms of
  - Fuel
  - Reaction Temperature
  - Energy released per kg of fuel
  - Energy-Releasing Reactions
  - Region of the atom involved in the reaction

	Chemical	Fission	Fusion
Sample Reaction	$C + O_2 \rightarrow CO_2$	n + U-235 -> Ba-143 + Kr-91 + 2 n	H-2 + H-3 -> He-4 + n
Typical Inputs (to Power Plant) (Fuel)	Bituminous Coal	UO_2 (3% U-235 + 97% U-238)	Deuterium & Lithium
Typical Reaction Temperature (K)	700 K	1000 K	10^8 K
Energy Released per kg of Fuel (J/kg)	3.3×10^7 J/kg	2.1×10^{12} J/kg	3.4×10^{14} J/kg

Traditional Chemistry Differentiation

- Write and balance equations for a fission reactions (for example)
  - $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{142}_{56}Ba + {}^{91}_{36}Kr + 3\,{}^{1}_{0}n$
  - $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n$
  - $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{137}_{52}Te + {}^{97}_{40}Zr + 2\,{}^{1}_{0}n$
  - Etc.
- Write and balance equations for a fusion reactions (for example)
  - $2\,{}^{1}_{1}H \longrightarrow {}^{2}_{1}H + {}^{0}_{-1}e$
  - $^{1}_{1}H + {}^{2}_{1}H \longrightarrow {}^{3}_{2}He + \gamma$
  - $2\,{}^{2}_{1}H \longrightarrow {}^{3}_{1}H + {}^{1}_{1}H$
  - $2\,{}^{3}_{2}He \longrightarrow {}^{4}_{2}He + 2\,{}^{1}_{1}H$
  - Etc.

Assessment

As stated in the indicator, the major focus of assessment is to <u>compare</u> (detect correspondences) in the nuclear reactions of fission and fusion to chemical reactions. Because the indicator is written as <u>conceptual knowledge,</u> assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students understand the processes in terms of the differences in the parts of the atom involved and the relative energy released.

C-2.5 Compare alpha, beta, and gamma radiation in terms of mass, charge, penetrating power, and the release of these particles from the nucleus.

Revised Taxonomy Level 2.6 <u>Compare</u> conceptual knowledge

This concept was not addressed in physical Science

It is essential for students to

- Understand the type of radiation that may be emitted during nuclear reactions

Type of radiation emitted & symbol	Nature of the radiation	Nuclear Symbol	Penetrating power, and what will block it	Effect of release of particles from the nucleus
α **Alpha**	a helium nucleus of 2 protons and 2 neutrons, mass = 4, charge = +2	$^{4}_{2}He$	Low penetration stopped by a few cm of air or thin sheet of paper	Reduces the atomic mass number by 4 Reduces the atomic number by 2
β **Beta**	high kinetic energy electrons, mass = 1/1850 of alpha, charge = -1	$^{0}_{-1}e$	Moderate penetration, most stopped by a few mm of metals like aluminum	Is the result of neutron decay and will increase the atomic number by 1 but will not change the mass number
γ **Gamma**	very high frequency electromagnetic radiation, mass = 0, charge = 0	$^{0}_{0}\gamma$	Very highly penetrating, most stopped by a thick layer of steel or concrete, but even a few cm of dense lead doesn't stop all of it!	Is electromagnetic radiation released from an excited nucleus. The atomic number and mass number do not change.

Assessment

As stated in the indicator, the major focus of assessment is to <u>compare</u> (detect correspondences) in the most common types of radiation that are released during nuclear reactions. Because the indicator is written as <u>conceptual knowledge,</u> assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students understand how the structure of the particle determines its penetrating effect and ionization power.

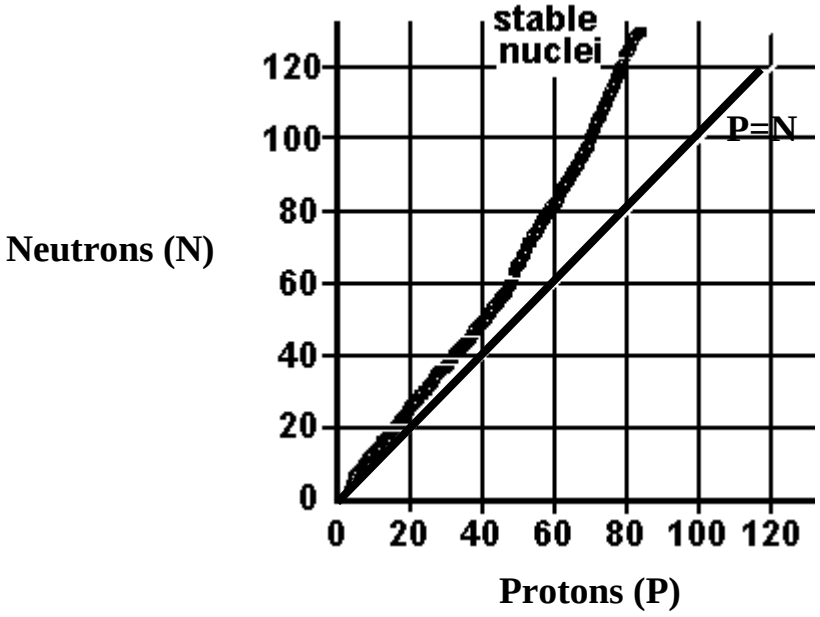
C-2.6 Explain the concept of half-life, its use in determining the age of materials, and its significance to nuclear waste disposal.

Revised Taxonomy Levels 2.7 B <u>Explain</u> conceptual knowledge
Key concepts

This topic was not addressed in physical science

It is essential for students to

- Understand that only certain combinations of protons and neutrons seem to be stable (see stability curve graph). Any isotope of any element that does not lie in the stability band with a stable neutron/proton ratio is likely to be radioactive.



  - There are no stable nuclei with an atomic number higher than 83 or a neutron number higher than 126.
  - The more protons in the nuclei, the more neutrons are needed for stability.
    - The stability band pulls away from the P=N line.
  - Stability is favored by even numbers of protons and even numbers of neutrons.
- Understand that radioactivity results from the random and spontaneous breakdown of the unstable nucleus of an atom. This breakdown is called radioactive decay of the unstable atom/nucleus/radioisotope.
  - In the breakdown of the unstable nucleus, energy is released by the emission of alpha, beta and gamma ionizing radiation.
  - The breakdown of an unstable atom is referred to as decay or disintegration and is a random process meaning it is a matter of chance which particular nucleus decays.

- Understand that not all of the atoms of a radioisotope decay at the same time, but they decay at a rate that is characteristic to the isotope. The rate of decay is a fixed rate called a half-life.
  - The half-life of a radioisotope describes how long it takes for half of the atoms in a given mass to decay.
  - Some isotopes decay very rapidly and, therefore, have a high specific activity. Others decay at a much slower rate.
- Understand carbon dating
  - As soon as a living organism dies, it stops taking in new carbon.
  - The ratio of carbon-12 to carbon-14 at the moment of death is the same as every other living thing, but the carbon-14 decays and is not replaced.
  - The carbon-14 decays with its half-life of 5,700 years, while the amount of carbon-12 remains constant in the sample.
  - By looking at the ratio of carbon-12 to carbon-14 in the sample and comparing it to the ratio in a living organism, it is possible to determine the age of a formerly living thing fairly precisely.
- Understand how the half life of nuclear waste determines how it is processed and stored.

Assessment

The verb, explain means that the major focus of assessment should be for students to "construct a cause and effect model". In this case, assessments will ensure that students can model how the half life of a radioactive element determines its effect on the environment. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students can construct a cause and effect statement relating how the nuclear structure of the atom determines its stability, and the process and consequences of the decay of unstable elements.

The following three indicators (2.7 – 2.9) should be selected as appropriate to a particular course for additional content and depth:

C-2.7 Apply the predictable rate of nuclear decay (half-life) to determine the age of materials.

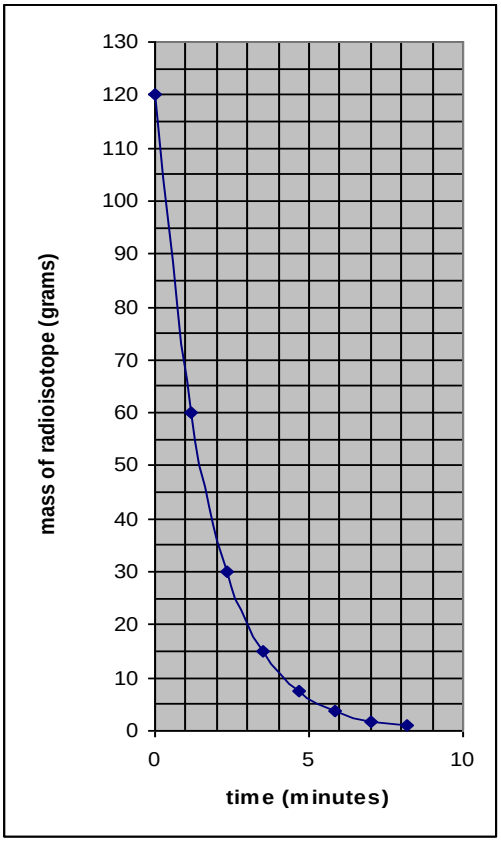
Revised Taxonomy Level 3.2 C_A <u>Apply</u> (<u>use</u>) procedural knowledge
Students did not address this concept in physical science

It is essential for students to

- Determine the half life of a substance when given the change in the mass of the radioisotope over time. (for example)
  - Given:
    - The initial mass of Protoactinium-23 is120 g
    - The final mass is 1.88 g
    - The elapsed time is 7 minutes
  - The sequence for decays would be:
    - 120g>60g>30g>15g>7.5g>3.75g>1.88g
    - This is 6 half lives.
  - So one half life is
    - 7 minutes / 6 = 1.17 minutes.
- Interpolate the age of a substance at a given time using a graph of mass vs time
  - Make a chart by adding 1.17 minutes (the calculated half life) for successive time periods and dividing the mass in half for each successive time period.

Mass (grams)	Time (minutes)
120	0
60	1.17
30	2.34
15	3.51
7.5	4.68
3.75	5.85
1.875	6.92

- Graph the data



Rate Laws are beyond the scope of most introductory chemistry courses

Assessment

The revised taxonomy verb for this indicator is implement (use), the major focus of assessment will be for students to show that they can "apply a procedure to an unfamiliar task". The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods" In this case the procedure for determining the half-life of a substance from laboratory data and the use of that data to determine the age of a given specimen. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat problems which are familiar. This requires that students have a conceptual understanding of the decay of radioactive isotopes

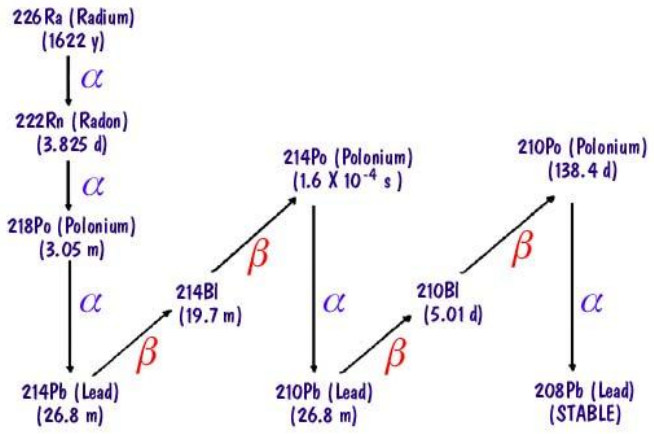
C-2.8 Analyze a decay series chart to determine the products of successive nuclear reactions and write nuclear equations for disintegration of specified nuclides

Revised Taxonomy Level 4 **<u>Analyze</u> conceptual knowledge**

Students did not address this concept in physical science

It is essential for students to

- Interpret a radioactive decay series such as the one below



Radium-226 (Uranium-238) decay series with half-lives.

- Write and balance nuclear equations for each of the steps in a decay series
  - $^{226}_{88}Ra \longrightarrow {}^{222}_{86}Rd + {}^{4}_{2}He$
  - $^{222}_{86}Rd \longrightarrow {}^{218}_{84}Po + {}^{4}_{2}He$
  - $^{218}_{84}Po \longrightarrow {}^{214}_{82}Pb + {}^{4}_{2}He$
  - $^{214}_{82}Pb \longrightarrow {}^{214}_{83}Bi + {}^{0}_{-1}e$
  - Etc.

Assessment

The revised taxonomy verb for this indicator is analyze which means to "break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose". In this case, students should be able to look at the decay series diagram and determine the particles which are produced by each successive step. Because the indicator is written as <u>conceptual knowledge,</u> assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students understand the reasons for the values of mass number and atomic number for each of the substances and particles.

C-2.9 Use the equation $E = mc^2$ to determine the amount of energy released during nuclear reactions.

This concept was not addressed in physical science

Revised Taxonomy Level 3.2 C_A <u>Apply</u> (<u>use</u>) procedural knowledge

Students did not cover this concept in physical science

It is essential for students to

- Calculate nuclear binding energies
  - Calculate the change in potential energy that would occur if the nucleus were formed from its constituent protons and neutrons (for example $^{16}_{8}O$)
  - $8\,^{1}_{0}n + 8\,^{1}_{1}H \longrightarrow {}^{16}_{8}O$
  - Obtain the energy change by comparing the sum of the mass of eight protons and eight neutrons with that of the oxygen nucleus
    - The mass of the oxygen nucleus, protons and neutrons will need to be supplied to 5 decimal places
    - 8 (1.67493×10^{-24}g) + 8 (1.67262×10^{-24}g) = 2.67804×10^{-23}g

      8 (mass of $^{1}_{0}n$) + 8(mass of $^{1}_{1}H$) = total mass of protons & neutrons
    - Mass of $^{16}_{8}O$ nucleus = $2.65535 \times 10^{10-23}$g
    - 2.65535×10^{-23}g - 2.67804×10^{-23}g = -2.269×10^{-25}g
      - The negative sign means the process is exothermic
    - The difference in energy is called the mass defect
- The mass defect is the amount of mass which is converted to energy in a nuclear reaction using the equation: $E = mc^2$, where
  - E = energy (in joules per atom)
  - m = mass defect (in kg)
  - c = the speed of light (3.00×10^{8}m/s)

Assessment

The revised taxonomy verb for this indicator is <u>implement</u> (<u>use</u>), the major focus of assessment will be for students to show that they can "apply a procedure to an unfamiliar task". The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods" In this case the procedure for producing an electric field drawing. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat problems which are familiar. This requires that students have a conceptual understanding of electric charge and electric fields.

Standard C-3: The student will demonstrate an understanding of the structures and classifications of chemical compounds.

Supporting Content Web Sites

Density
www.nyu.edu/pages/mathmol/textbook/density.html
This site describes density using visuals and formulas. It also includes calculations for students to submit online.
PS-3.1

Physical and Chemical Properties and Changes
www.fordhamprep.org/gcurran/sho/sho/lessons/lesson15.htm
Physical and chemical properties are described. Worksheets and online quizzes are available.
PS-3.1

Review and Practice on Chemical vs. Physical Properties and Changes
www.teacherbridge.org/public/bhs/teachers/Dana/chemphys.html
This site contains reviews of the concepts of chemical and physical properties and changes. It also has an online practice activity.
PS-3.1

Soap and Detergent Chemistry
www.sdahq.org/cleaning/chemistry
This site gives information about how soap works, including a description of how nonpolar oils are used in soaps.
PS-3.2

What is the difference between a compound and a molecule?
http://education.jlab.org/qa/compound.html
This question and answer site answers questions relating to compounds and molecules.
PS-3.3

The Dissolving Process
www.geocities.com/capecanaveral/Lab/1643/solutions2.html
This site examines the process of a solid dissolving in a liquid as well as factors affecting the rate of dissolving.
PS-3.5

Elements, Mixtures, and Compounds
http://www.darvill.clara.net/hotpots/emc.htm
The site is comprised of a matching game that allows students to match types of mixtures and compounds to diagrams.
PS-3.4

Skool.co.uk Chemistry
http://lgfl.skoool.co.uk/keystage3.aspx?id=64
This site has a huge variety of chemistry topics including properties and states of matter, particle theory of matter, change in state, reactions of metals in acid, reactivity series of metals, acid and alkalis, acid base reactions and the pH scale.
PS-3.1, PS-3.6, PS-3.7, PS-3.8

GEMS Alien Juice Bar
http://sv.berkeley.edu/showcase/flash/juicebar.html
This site contains games that challenge students to learn about acids, bases, neutrals, and Ph.
PS-3.8

S-Cool Chemistry GCSE Acids and Alkalis
http://www.s-cool.co.uk/topic_principles.asp?loc=pr&topic_id=1&subject_id=21&ebt=212&ebn=&ebs=&ebl=&elc=4
This site provides review of the concepts of acid and alkali properties and explains the uses of neutralization. It also has sample questions for practice.
PS-3.8

Suggested Literature

Gardner, R. (2004). *Science Fair Projects About the Properties of Matter Using Marble, Water, Balloons, and More*. Berkeley Heights, NJ: Enslow Publishers, Inc.
ISBN: 0-7660-2128-9
Lexile Level: NA
This book includes descriptions of elastic properties, properties of solids and liquids, and density of solids, liquids, and gases.
PS-3.1

Newmark, A. (2005). *Eyewitness Books-Chemistry*. New York: DK Publishing, Inc.
ISBN: 0-7566-1385-X
Lexile Level: NA
This book investigates mixtures and how they are separated, discerns atoms from molecules, and investigates elements and compounds. It also examines acids and bases with using pH and a discussion of indicators.
PS-3.4 and PS-3.8

Baldwin, C. (2006). *States of Matter*. Chicago: Raintree
ISBN: 1-41091-678
Lexile Level: NA
This book includes discussions on the properties of solids, liquids, gases, and plasmas. It also examines how matter changes states.

PS-3.6

The Facts on File Dictionary of Inorganic Chemistry. (2004). New York: Facts on File
ISBN: 0-8160-4926-2
Lexile Level: NA
This book gives definitions as well as explanations of terms associated with inorganic chemistry. It also provides illustrations.
PS-3.2

The Facts on File Dictionary of Organic Chemistry. (2004). New York: Facts on File
ISBN: 0-8160-4928-9
Lexile Level: NA
This book includes alphabetized entries on common organic terms.
PS-3.2

Hayhurst, Chris. (2003). *Bifuel Power of the Future: New Ways to Turning Organic Matter into Energy.* Springfield, NJ: Rosen Publishing Group
ISBN: 0-8239-3659-7
Lexile Level: NA
This book examines the pros and cons of using plant and animal wastes (organic matter) to meet our growing energy needs.
PS-3.2

Suggested Streamline Video Resources:

Physical Science Series: Properties of Matter

Characteristics of Matter
ETV Streamline SC
Describes properties as chemical and physical properties and gives examples.
1:26-5:19
PS-3.1

Physical Science Series: Properties of Matter

Density
ETV Streamline SC
This video shows application and formula of density. Also includes problem solving exercise.
8:20- 10:02
PS-3.1

Physical Science Series: Mixtures and Solutions
Solubility
ETV Streamline SC
This video describes solubility in terms of mass and temperature. Graphs are used to describe saturated and unsaturated solutions.
11:29 – 15:44

PS-3.1

Physical Science Series: Phases of Matter

Melting and Vaporization and Condensation, Freezing, and Sublimation
ETV Streamline SC
These two video segments explain the physical properties of freezing, condensation, melting, evaporation and sublimation.
5:12 -9:12
PS-3.1

Elements of Chemistry: Carbon: The Element of Life

Polymers and Plastics
ETV Streamline SC
Demonstrates applications of synthetic organic polymers and describes their properties.
13:08 – 15:26
PS- 3.2

Energy and the Chemistry of Life

Atoms and Elements and Molecules, Compounds, and Chemical Bonds
ETV Streamline SC
These segments explain the parts of the atom and compares sizes of atoms of different elements. It also explains bonding of molecules as a result of chemical reactions and gives a good description of chemical formulas.
22:54 – 29:15
PS- 3.3

Physical Science Series: Mixtures and Solutions

Classification of Matter and Mixtures
ETV Streamline SC
This video explains differences in heterogeneous and homogeneous mixtures and classifies these mixtures as colloids, suspensions, and solutions. It also explains the terms solute and solvent.
0:00 -7:29
PS-3.4

Physical Science Series: Mixtures and Solutions
Solubility
ETV Streamline SC
Agitation, particle size, and temperature are all examined as they relate to the rate of dissolving.
7:29-9:29
PS-3.5

Elements of Chemistry: Gases, Liquids, and Solids
Different States of Matter

ETV Streamline SC
This segment distinguishes among the attraction of particles in solids, liquids, and gases. It also describes how temperature is related to change of state.
8:30-12:10
PS-3.6

Physical Science Series: Phases of Matter

Phase Changes
ETV Streamline SC
This segment defines changes in matter due to heat transfer and temperature.
8:11-13:50
PS-3.7

Chemistry Connections: Kinetic and Potential Energy Changes during Changes to States of Matter

Phase Changes and Temperature-Time Graphs
ETV Streamline SC
This segment shows the use of probes to measure temperature changes throughout an experiment. Graphing using computers is also described.
1:04-12:43
PS-3.7

Elements of Chemistry: Acids, Bases and Salts
Properties of Acids and Bases
ETV Streamline SC
This segment gives several good examples of the properties of acids and bases.
0:00- 3:14
PS-3.8

Elements of Chemistry: Acids, Bases, and Salts

Strong and Weak Acids and Bases
ETV Streamline SC
The leveling of pH and water's ability to act in neutralization are described in this segment.
8:15-10:46
PS-3.8

Chemistry Connections: Acids and Bases Defined
Empirical Definition of Acid and Base Solutions
ETV Streamline SC
The properties and chemical activity of acids and bases are described in this segment. Also included are the uses of litmus, pH probes, and reactions with metals.
7:03-21:02
PS-3.8

Career Connections

Chemistry Professor/Teacher
Chemistry educators work using educational methods to teach students to appreciate how matter is composed and how it behaves. They also use mathematics to solve problems related to chemistry concepts. University professors will also do research and publish their findings.

Chemical Engineer
Chemical engineers use chemical laboratory processes in an industrial setting in order to produce products such as fertilizers, pharmaceuticals, plastics, and food preservatives.

Inorganic Chemist
An inorganic chemist primarily works with metals. They are especially important in the electronics industry where they have used their knowledge of materials chemistry to build components such as integrated circuits.

Organic Chemist
An organic chemist often works with petroleum, wood products, plastics, textiles, as well as in the food industry. They may design new production processes for older materials as well as the development of synthetic materials.

Physical Chemist
A physical chemist will study the physical properties of matter. Some topics they may study include the statistics on molecular interactions, combustion of plasma, and nuclear reactions.

C-3.1 Predict the type of bonding (ionic or covalent) and the shape of simple compounds by using Lewis dot structures and oxidation numbers.

Revised Taxonomy Level 2.5-B Infer (predict) conceptual understanding

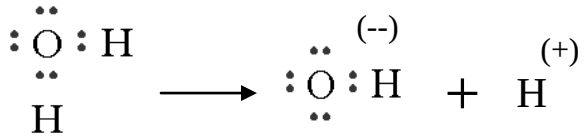
In Physical Science students

- Explain the role of bonding in achieving chemical stability. (PS-4.1)
- Explain how the process of covalent bonding provides chemical stability through the sharing of electrons. (PS-4.2)
- Illustrate the fact that ions attract ions of opposite charge from all directions and form crystal lattices. (PS-4.3)
- Classify compounds as crystalline (containing ionic bonds) or molecular (containing covalent bonds) based on whether their outer electrons are transferred or shared. (PS-4.4)
- Predict the ratio by which the representative elements combine to form binary ionic compounds, and represent that ratio in a chemical formula. (PS-4.5)

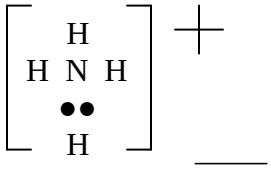
It is essential for students to

- Understand that the structure of molecules is the result of nonmetals sharing electrons in order to form stable outer-energy-level configuration. (covalent bonds)
  - Understand that because orbitals in the outer energy level of an atom are most stable when they contain two electrons, a covalent bond is likely to form between two elements which will both achieve the status of a full orbital in the outer energy level.
    - Covalent bonds are common between two elements, each having one or more orbitals in the outer energy level containing only one electron.
  - Understand how single, double, and triple bonds are formed.
  - Understand that the "s" and "p" orbitals in the outer energy level of each atom provide four possible bonding sites (except for the elements which achieve He structure)
  - Understand the 3-dimensional nature of molecules (tetrahedral bonding site structure)
  - Explain the shape of simple molecules such as water and carbon dioxide using VESPR
  - Draw Lewis dot structures for simple molecules
- Understand that crystalline structure is the result of the ionic bonding of positive and negative ions, forming a neutral compound.
  - The sum of the oxidation numbers in the formula of any neutral compound is zero
  - Understand that metallic atoms can form positive monatomic ions by losing electrons in order to achieve a stable outer energy level electron structure
  - Understand that nonmetal atoms can form negative monatomic ions by gaining electrons in order to achieve a stable outer energy level electron structure
  - Know that the oxidation number of a monoatomic ion is equal to its charge
  - Know the oxidation number of the monoatomic ions formed from elements in the following groups of the periodic table

- Group 1, +1
- Group 2, +2
- Group 16, -2
- Group 17, -1
- Understand that some covalently bonded groups of atoms (similar in structure to molecules) act like single atoms in forming ions. These charged groups of covalently bonded atoms are called polyatomic (many-atomed) ions and may be positive or negative.
- This most frequently occurs when a molecule loses one or more hydrogen ions (H^+), leaving the species negatively charged, such as the disassociation of water into a hydroxide ion (OH^-) and a hydrogen ion (H^+)



- The ammonium ion is formed when a molecule of ammonia, (NH_3), combines with a hydrogen ion, (H^+), resulting in a positively charged species. (NH_4^+)



- Such a species is called a polyatomic ion
- Understand that the oxidation number of a polyatomic ion is equal to its charge
- Understand that polyatomic ions react exactly the same as monoatomic ions in chemical reactions
- Use Lewis dot formulas to demonstrate ionic bonding

Assessment Guidelines

The objective of this indicator is for students to <u>infer (predict)</u> the type of bond and the shape of a simple compound (draw a logical conclusion) based on the outer energy level electron structure of the component elements. As this is <u>conceptual knowledge</u> (knowledge of the interrelationships among the basic elements within a large structure that enable them to function together) the primary focus of assessment should be to show that students can use knowledge of chemical stability and the relationship between an element's position on the periodic table and outers-level electron arrangement to predict whether an atom will gain, lose or share electrons, and how many electrons will be involved. In addition, students should have an understanding that many atomic properties are a result of an atoms tendency to gain or lose electrons.

C-3.2 Interpret the names and formulas for ionic and covalent compounds.

Revised Taxonomy Level 2.1 B Interpreting conceptual knowledge

In Physical Science Students

- Predict the ratio by which the representative elements combine to form binary ionic compounds, and represent that ratio in a chemical formula. (PS-4.5)

It is essential for students to

- Name and write the chemical formulas for binary molecular compounds
- Name and write the chemical formulas for ionic compounds including those that contain common polyatomic ions
- Identify substances as molecular or ionic compounds
- Compare molecular and ionic compounds according to their properties
- Differentiate and write molecular formulas, empirical formulas and structural formulas

Assessment

Since the verb for this indicator is interpret (represent) the major focus of assessment will be for students to "change from one form of representation to another". In this case, write the name of a chemical compound when given the formula, or write the formula when given the name. As this indicator is classified as conceptual knowledge, it is vital that students understand the protocol for naming and writing the formulas for chemical substances and can apply their knowledge of chemical nomenclature to any chemical formula or name of a chemical compound or substance.

C-3.3 Explain how the types of intermolecular forces present in a compound affect the physical properties of compounds (including polarity and molecular shape).

Revised Taxonomy Levels 2.7 B Explain conceptual knowledge

Students did not study this concept in physical science

It is essential for students to

- Understand that ionic bond and covalent bond are relative terms and that most bonds that we characterize as ionic or covalent actually have a character that lies somewhere between 100% ionic and 100% covalent
  - Bonds between active metals and active nonmetals are characterized by a high degree of ionic character because electron transferred is virtually complete
    - Because ionic bonds are very strong, substances with ionic bonds usually have high melting and boiling points
  - Bonds between identical non metals (diatomic compounds) are characterized by zero percent ionic character because electrons are shared equally.
  - Bonds between other substances (such as the bond between oxygen and hydrogen) have an intermediate nature; the shared electrons are not shared equitably but spend more time with whichever atom is more electronegative.
    - The atom with the stronger attraction for electrons becomes partially negatively charged
    - The atom with the lower electronegativity value becomes partially positively charged
    - Covalent bonds that do not share the electrons equally are called polar covalent bonds
    - Covalent bonds that do share the electrons equally are called non-polar covalent bonds
    - If the polar bonds in a molecule are all alike, the polarity of the molecule as a whole depends only on the arrangement in space of the bonds (water molecules are polar due to bent structure)
    - Polar molecules are attracted to one another, but the attraction is not a chemical bond so it is broken easily. These substances usually have moderate melting and boiling points
    - Polar molecules are attracted to one another and to ionic substances as well

Assessment

The verb, explain means that the major focus of assessment should be for students to "construct a cause and effect model". In this case, assessments will ensure that students can model how intermolecular forces affect the properties of a substance. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students can construct a cause and effect statement relating how intermolecular forces which are

determined by the type of bonding within a substance, affect the properties of the substance.

C-3.4 Explain the unique bonding characteristics of carbon that have resulted in formation of a large variety of organic structures.

Revised Taxonomy Levels 2.7 B <u>Explain</u> conceptual knowledge

Students did not study this concept in physical science

It is essential for students to

- Understand bonding in the allotropic forms of carbon, diamond and graphite
- Describe hybridization (sp^3) of simple molecules
- Understand how the capacity to form four covalent bonds results in several bonding possibilities for carbon, including
  - Single, double, and triple bonds
  - Ring structures
  - Covalent network

Assessment

The verb, <u>explain</u> means that the major focus of assessment should be for students to "construct a cause and effect model". In this case, assessments will ensure that students can model sp^3 hybridization for many possible bonding configurations for carbon. Because the indicator is written as <u>conceptual knowledge,</u> assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students can construct a cause and effect statement relating how sp^3 hybridization allows for four lone electrons and therefore many possible bonding configurations.

C-3.5 Illustrate the structural formulas and names of simple hydrocarbons (including alkanes and their isomers and benzene rings).

Revised Taxonomy Level 2.2-B Exemplify (illustrate) conceptual knowledge

Students did not cover this standard in physical science

It is essential for students to

- Understand International Union of Pure and Applied Chemistry (IUPAC) organic nomenclature
- Name and write the formula for alkanes (up to 10-carbon), their isomers and benzene rings
- Draw the structural formulas for alkanes up to a 10-carbon chain

Assessment

The verb exemplify (illustrate) means to find a specific example or illustration of a concept or principle, therefore the major focus of assessment will be for students to give examples that show that they understand the organic nomenclature for organic alkanes and their isomers. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together, in this case, that students understand how the structure of the molecule determines its name.

The following five indicators (C-3.6-C3.10) should be selected as appropriate to a particular course for additional content and depth:

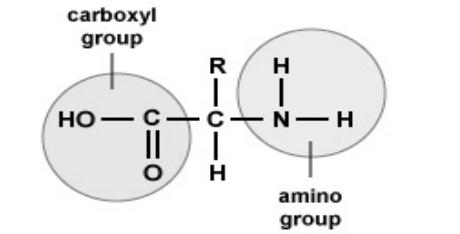
C-3.6 Identify the basic structure of common polymers (including proteins, nucleic acids, plastics, and starches). (additional content/depth)

Revised Taxonomy Level 1.1 B (Identify conceptual knowledge)

Students did not study this concept in physical science

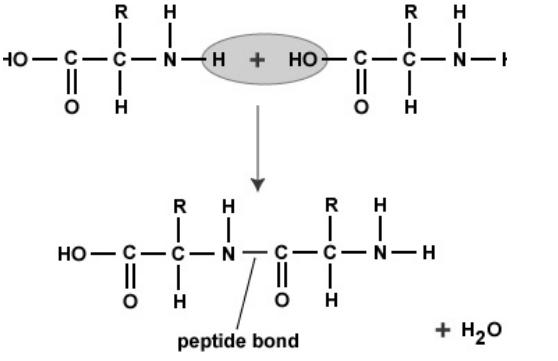
It is essential for students to

- Recognize the basic structure of a protein as that of a polymer composed of monomers of amino acids.
  - The basic structure of an amino acid is



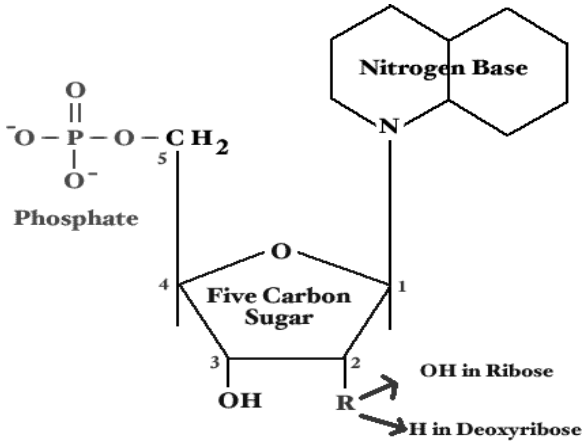
Amino Acid

  - Where "R" represents H, CH_3 or a more complex organic functional group
  - Understand that there are 20 amino acids commonly found in proteins, that differ with regard to the "R" group
  - Understand that peptide bonds are formed between the amino acids to form proteins



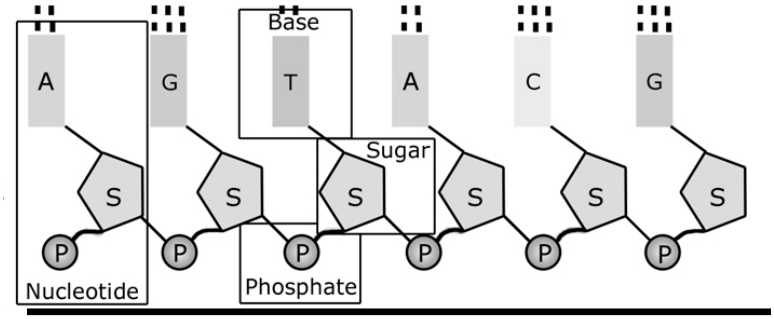
Protein

- Recognize the basic structure of a nucleic acid as that of a polymer composed of monomers of nucleotides.
  - The basic structure of a nucleotide is that of a



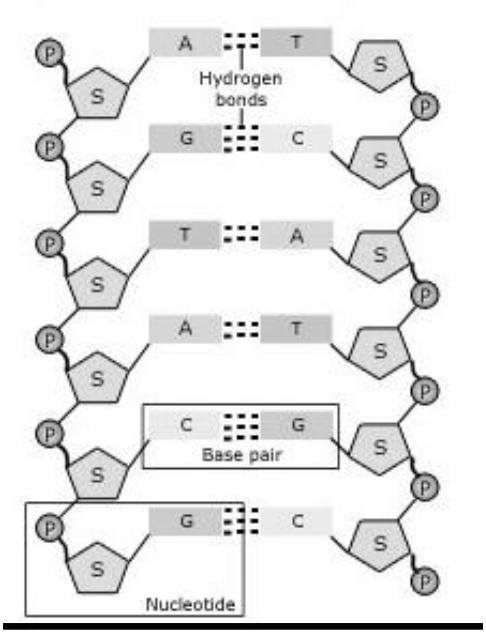
Nucleotide

- An organic functional group ("R") representing H, CH_3 or a more complex organic functional group
- Phosphate
- A five-carbon sugar
- A nitrogen base (the structure of the nitrogen base varies with different nucleic acids)
  - Uracil (U)
  - Cytosine (C)
  - Thymine (T)
  - Adenine (A)
  - Guanine (G)
- The nucleotides form the nucleic acid polymer by bonding between sugars and phosphates



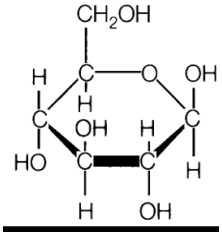
Single stranded DNA

- Duplication of the polymers result from bonding at the bases
  - T only bonds with A or U
  - G only bonds with

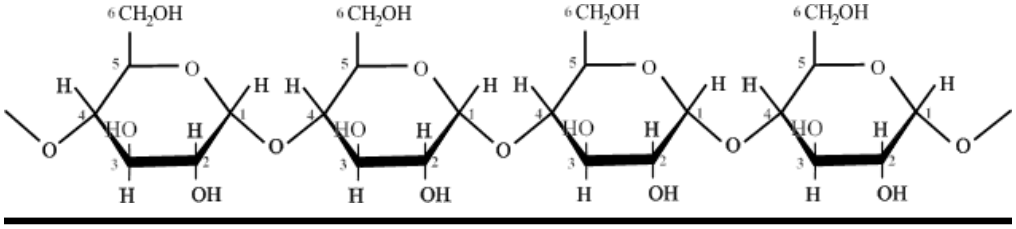


Double Stranded DNA

- Recognize the basic structure of carbohydrate as that of a polymer composed of monomers called monosaccharides (simple sugars).
  - Monosaccharides contain carbon hydrogen and oxygen in a ratio of 1:2:1 which gives an empirical formula of CH_2O
  - Starch is composed of monosaccarides of glucose



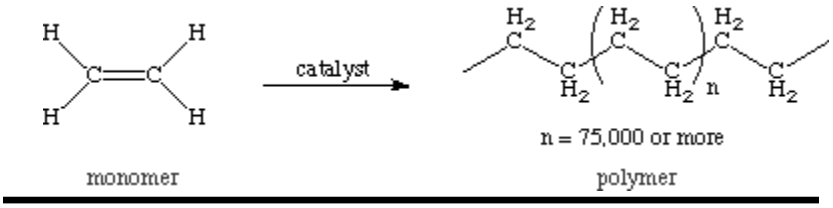
Glucose



Starch

- Understand that a plastic is a synthetic polymer (polymer prepared in the laboratory or industry) that is easily molded.
  - There are two types of plastic
    - Thermoplastics which soften or melt when heated
    - Thermosetting plastics which harden or set when heated and do not remelt

- Recognize the basic structure of a plastic as that of a polymer composed of monomers derived from petroleum
  - An example is polyethylene with monomers of ethylene



Ethylene **Polyethylene**

Assessment

As the verb for this indicator is recognize (identify), the major focus of assessment should be for students to "locate knowledge in long term memory that is consistent with presented material; in this case, for students to be able to identify the substances presented here as polymers, and to recall the general composition and the name of the monomers which compose them when presented with diagrams or descriptions of the substances. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together, in this case, that students know how the parts of each polymer come together to form the whole.

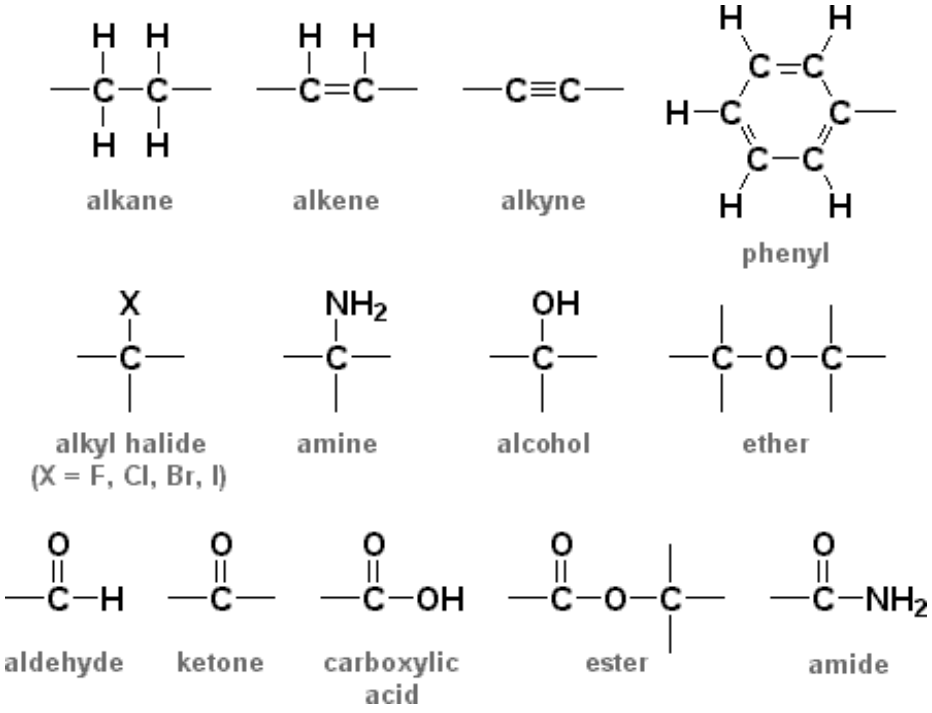
C-3.7 Classify organic compounds in terms of their functional group. (additional content/depth)

Revised Taxonomy Level 2.3 B (Classify conceptual knowledge)

This concept was not covered in physical science

It is essential for students to

- Name and draw structural formulas of alkenes, alkynes, benzene and cyclohexanes.
- Define the term functional group
- Recognize the following functional groups when presented with the structural formula of a compound
- Understand the rules of organic nomenclature as they apply to naming compounds which contain each of the following functional groups



Assessment

As the indicator states, the major focus of assessment is to classify organic substances based on the functional group as illustrated by a structural formula.

As the taxonomy verb is classify as opposed to distinguish, the assessment item should include all of the relevant information that is needed to make the distinction between categories, students should not have to pick out the relevant information.

As the indicator has a cognitive dimension of conceptual knowledge, assessment items will require that students understand each of these categories in terms of the "interrelationships among the basic elements within the category", in other words students must show that they understand the criteria for each category. Assessments will require that students can classify any given structural formula.

C-3.8 Explain the effect of electronegativity and ionization energy on the type of bonding a molecule. (additional content/depth)

Revised Taxonomy Levels 2.7 B Explain conceptual knowledge

This topic was not addressed in physical science

It is essential for students to

- Infer relative electronegativity values for elements based on the element's position on the periodic table.
- Use a table of electronegativity values to assign values to elements represented in the structural formula of a substance.
- Determine the percent ionic character of a bond based on the electronegativity difference of the elements involved
- Understand how the electronegativity difference can be used to classify the type of bond in a substance
- Infer relative ionization energy values for elements based on the element's position on the periodic table.
- Use a table of ionization energy values to assign values to elements represented in the structural formula of a substance.
- Understand how the relative ionization energies of two elements can be used to predict the type of bonding that form between them.
- Interpret the polarity of a molecule based on its geometry bond type.

Assessment

The verb, explain means that the major focus of assessment should be for students to "construct a cause and effect model". In this case, assessments will ensure that students can model electronegativity values or ionization energy values to predict the type of bonds that will form between two elements. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students can construct a cause and effect statement relating how the atomic structure of the element dictates its electronegativity and ionization energy values and that the student can make judgments concerning bond formation based on a comparison of either of these values.

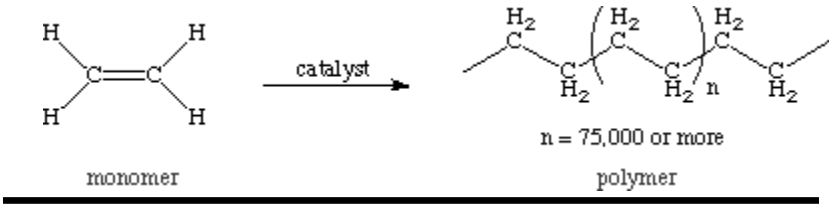
C-3.9 Classify polymerization reactions as addition or condensation (additional content/depth)

Revised Taxonomy Level 2.3 B (Classify conceptual knowledge)

Students did not address this topic in physical science

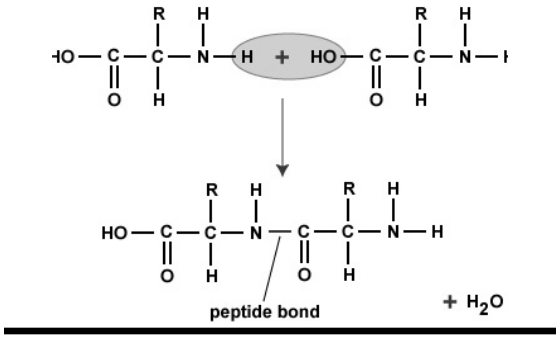
It is essential for students to

- Understand that an addition polymer is one which has been formed by chain addition reactions between monomers that contain a double bond.
  - For example, the polymerization of ethylene into polyethylene



Ethylene **Polyethylene**

- Understand that a condensation polymer is one which has been formed by two different parts of the same type of a molecule combining into long chains.
  - For example, the peptide bond in proteins



Protein formation from amino acids

Assessment

As the indicator states, the major focus of assessment is to classify polymers by the type of bonding. As the taxonomy verb is classify as opposed to distinguish, the assessment item should include all of the relevant information that is needed to make the distinction between categories, therefore, the bonding steps should be illustrated with structural formulas, diagrams or with verbal descriptions.

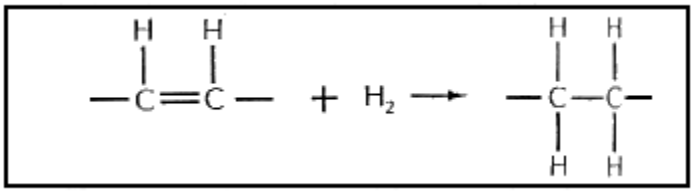
As the indicator has a cognitive dimension of conceptual knowledge, assessment items will require that students understand each of these categories in terms of the "interrelationships among the basic elements within the category", In other words students must show that they understand the criteria for each category.

C-3.10Classify organic reactions as addition, elimination, or condensation. (additional content/depth)

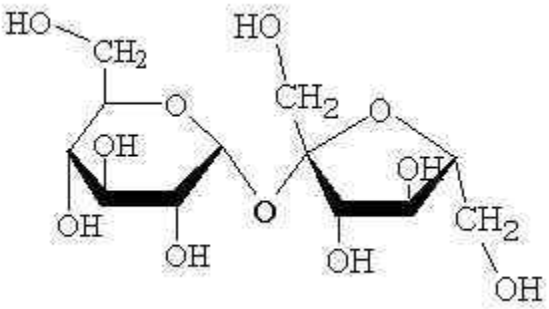
Revised Taxonomy Level 2.3 B (Classify conceptual knowledge)

Students did not address this topic in physical science
It is essential for students to

- Understand that an addition reaction is one in which an atom or molecule is added to an unsaturated molecule (one that has double or triple bonds) and increased the saturation of the molecule.
  - An example is the hydrogenation of vegetable oil



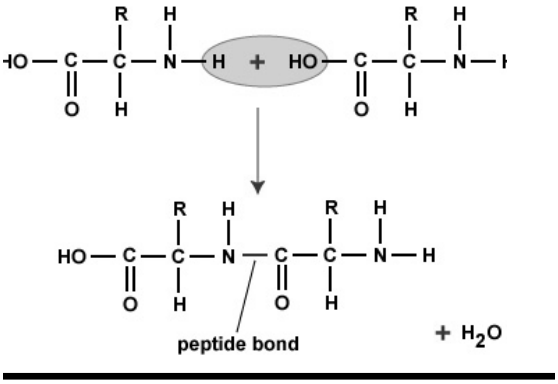
- Understand that an elimination reaction is one in which a simple molecule, such as water or ammonia, is removed from adjacent carbon atoms of a larger molecule.
  - An example is the dehydration of sucrose in the presence of sulfuric acid



Sucrose

$$C_{12}H_{22}O_{11\,(s)} \xrightarrow{H_2SO_4} 12C_{(s)} + 11\,H_2O_{(g)}$$

- Understand that a condensation reaction is one in which two molecules or parts of the same molecule combine.
  - An example of a condensation reaction is the formation of a protein from two amino acids



Protein

Assessment

As the indicator states, the major focus of assessment is to classify organic reactions. As the taxonomy verb is classify as opposed to distinguish, the assessment item should include all of the relevant information that is needed to make the distinction between categories, so the types of reactions should be illustrated with structural formulas, diagrams or with verbal descriptions.

As the indicator has a cognitive dimension of conceptual knowledge, assessment items should require that students understand each of these categories in terms of the "interrelationships among the basic elements within the category", in other words students must show that they understand the criteria for each category.

Standard C-4: The student will demonstrate an understanding of the types, the causes, and the effects of chemical reactions.

Supporting Content Web Sites

Virginia Tech Department of Chemistry
http://www.chem.vt.edu/RVGS/ACT/notes/Types_of_Equations.html
Provides a summary of the types of chemical reactions expressed as chemical equations with links to practice on balancing equations. Includes using an activity series for single replacement equations and predicting products of simple equations including combustion.
C-4.1, C-4.2

NOVA Online Fireworks: On Fire
http://www.pbs.org/wgbh/nova/fireworks/fire.html#
Provides a link to either a *Flash* or non-*Flash* version of an interactive review of a combustion reaction from the striking of a match to an atom by atom rearrangement of the molecules to create the products.
C-4.2

Iowa State University: Metals in Aqueous Solutions
http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/redox/home.html
Interactive simulation in which students choose metals to place into solutions in order to create a reactivity series. Choosing the "molecular scale reactions" will show an animation of the electron exchange process.
C-4.1, C-4.7

Iowa State University: Voltaic Cell
http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/electroChem/voltaicCellEMF.html
Interactive simulation of a voltaic cell in which students choose the electrodes and the solutions. Ions visually move within the solutions.
C-4.8

Iowa State University: Conductivity
http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/electroChem/conductivity.html
Interactive simulation of a conductivity experiment in which students control the electrolyte solution and the concentration of the solution to illuminate a light bulb.
C-4.8

Iowa State University: Equilibrium
http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/animations/no2n2o4equilV8.html
Simulation of an NO_2/N_2O_4 equilibrium. Students are directed to notice the changes in specific molecules and then to compare the number of each molecule at several stages.

C-4.9
Jefferson Lab: Balancing Act
http://education.jlab.org/elementbalancing/index.html
Interactive site in which students select the number and difficulty level of chemical equations to balance by choosing the correct coefficient from drop-down boxes. Answers are checked by the program and incorrect coefficients are highlighted for corrections.
C-4.1

Fun-based Learning: Chembalancer
http://funbasedlearning.com/chemistry/chembalancer2/default.htm
Students are provided chemical equations to balance by inserting the correct coefficients, and then as the coefficients are added, visual representations of the number of atoms are displayed. When students check their answers, a description of the importance of that chemical reaction in everyday life appears.
C-4.1

University of California-Irvine: Chemical Kinetics
http://www.chem.uci.edu/undergrad/applets/sim/simulation.htm
An applet that runs in real time showing the redistribution of simulated molecules to create a dynamic equilibrium. It is accompanied by a link to an instructions page where students will find a complete explanation of the simulation.
C-4.9

Suggested Literature

Keeler, J. (2003). *Why chemical reactions happen*. Oxford, UK: Oxford University Press.
ISBN: 0-19-924973-3
Lexile Level: Not available
Describes the way in which the concepts in a first year chemistry course are interconnected to create the conditions that cause a chemical reaction to occur. Students will enjoy the "story-line" format that emphasizes the major components of a chemical reaction rather than the mathematical details of the reaction mechanism.

Cobb, C. & H. Goldwhite (1995). *Creations of fire: chemistry's lively history from alchemy to the atomic age.* New York: Perseus Books Group.
ISBN: 0-7382-0594-X
Lexile Level: Not available
Students will find this an engaging illustration of the development of modern chemistry from the inexact practice of alchemy. The book provides descriptions of the way the tools and recipes of the ancient alchemists became the symbolism, equipment and reaction procedures of modern chemists, often relatively unchanged.

Suggested Streamline Video Resources

Simply Science: Combustion and Replacement Reactions

Combustion
ETV Streamline SC
Discussion of the combustion reaction using cellular respiration and the burning of fossil fuels to produce energy as examples. Includes an explanation of balancing a combustion equation and presents both complete and incomplete combustion products. Also presents a short discussion of the energy of collisions as a necessity for igniting a material.
6:38
C-4.1, C-4.2, C-4.3, C-4.10

Simply Science: Combustion and Replacement Reactions

ETV Streamline SC
Provides details and examples of both single and double replacement reactions with an explanation of balancing chemical equations of each type. Discusses the role of a solubility chart in determining which of the resulting products in a double replacement reaction will not be aqueous.
18:05-26:17
C-4.1

Chemistry Connections: Introduction to Thermochemical Changes

Endothermic and Exothermic Reactions
ETV Streamline SC
Gives several examples of both endothermic and exothermic reactions with a discussion of the energy changes in each. Most examples are based in real-world applications.
9:08
C-4.3

Chemistry Connections: Energy from the Sun

Catalysts
ETV Streamline SC
Uses the burning of a sugar cube dipped in acid, the decomposition of hydrogen peroxide, a car's catalytic converter, and CFC depletion of the ozone layer as demonstrations of the role of a catalyst. Provides a detailed discussion of the sugar reaction with an explanation of an energy diagram and activation energy.
6:32
C-4.6

Chemistry Connections: An Introduction to Oxidation and Reduction
ETV Streamline SC
Begins with a discussion of the extraction of metal from ores as in introduction to oxidation and reduction reactions. Provides examples of electrolytic and voltaic cells (though they are not named as such), balancing with half-cell reactions, and determining oxidizing and reducing agents.
29:05

C-4.7, C-4.8

Chemistry Connections: Dynamic Equilibrium

Forward and Reverse Rates in Concentration
ETV Streamline SC
A comical simulation of a reversible reaction that helps students understand a dynamic equilibrium. The simulation is accompanied by on-screen graphics using chemical symbolism to compare the forward and reverse rates.
4:17
C-4.4, C-4.9

Chemistry Connections: Opposing Reactions and Le Chatelier's Principle

ETV Streamline SC
Presents the Haber-Bosch process for producing ammonia and an analogy of people in a building as a means of explaining Le Chatelier's Principle. Also includes a demonstration of cobalt (II) coordination complexes with detailed analysis and a discussion of the use of a catalyst.
29:05
C-4.6, C-4.9

Career Connections

Chemical engineer

Chemical engineers develop and monitor chemical processes by determining the best reactants, reaction mechanisms, and reaction conditions (time, temperature, etc.) for producing the greatest yield of a desired product in the most efficient manner. Chemical engineers prepare written proposals and make presentations of their recommendations.

Chemical technician

Chemical technicians work with a chemist or chemical engineer to operate standard laboratory equipment. They set up apparatii for chemical reactions, perform chemical tests, and monitor reactions by checking quality of products, performance of equipment, and compliance with safety and pollution control standards. Chemical technicians are responsible for maintaining thorough and accurate laboratory records.

Electrolytic plating operator

Electrolytic plating operators run electrolytic plating or coating machines to coat metal or plastic products with chromium, zinc, copper, cadmium, or other metals to provide protective or decorative surfaces or to repair worn surfaces.

Catalytic chemist

Catalytic chemists specialize in the study of chemical reaction catalysts. Some are involved in the research and development of new catalysts or new uses of existing catalysts while others concentrate on the application of catalysts to chemical synthesis or industrial processes.

Pulp and paper chemist

Pulp and paper chemists specialize in the chemical processes required to produce paper products from wood pulp. They develop and monitor chemical reactions that extract the cellulose from pulp, bleach and dye the paper, size the paper for surface characteristics, and regulate the desired strength of the paper for a given application.

C-4.1 Analyze and balance equations for simple synthesis, decomposition, single replacement, double replacement, and combustion reactions.

Revised Taxonomy Level 4 **<u>Analyze</u> conceptual knowledge**

In Physical Science, Students:

- Apply a procedure to balance equations for a simple synthesis or decomposition reaction. (PS-4.9)
- Recognize simple chemical equations (including single replacement and double replacement) as being balanced or not balanced. (PS-4.10)

It is essential for students to:

- Classify typical chemical equations based on the composition of the reactants
  - Single replacement
  - Double replacement
  - Synthesis (composition)
  - Decomposition
  - Combustion
- Balance any chemical reaction when given the reactants and the products, including the notations used to indicate the phase of the substance.
  - $Cl_2(g)$ chlorine gas
  - $H_2O(\ell)$ water as a liquid
  - $NaCl(s)$ sodium chloride as a solid
  - $NaCl(aq)$ sodium chloride dissolved in water

Assessment

The revised taxonomy verb for this indicator is analyze, which means to "break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose". Because the indicator is written as <u>conceptual knowledge,</u> assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together". In this case, that students understand how selected chemical compounds react in order to predict the products of chemical reactions, and then apply appropriate protocol and procedures for writing and balancing chemical equations to represent the equation in the accepted form.

C-4.2 Predict the products of acid-base neutralization and combustion reactions.

Revised Taxonomy Level 2.5-B Infer (predict) conceptual understanding

In physical science, students:

- Classify various solutions as acids or bases according to their physical properties, chemical properties (including neutralization and reaction with metals), generalized formulas, and pH (using pH meters, pH paper, and litmus paper). (PS-3.8)

It is essential for students to

- Predict the products for selected chemical reactions when given the reactants.
  - Single replacement
    - Students should know how to use a table showing The Activity Series of the Elements
      - Replacement of a metal with a more active metal
      - Replacement of hydrogen in an acid by a metal
  - Double replacement
    - Students should know how to use a table of solubility rules
      - Formation of a precipitate including
        - Formula equation
        - Ionic equation
        - Net ionic equation
      - Neutralization
  - Synthesis
  - Combustion of hydrocarbons

- **Assessment Guidelines**

The objective of this indicator is for students to <u>infer</u> (predict), or draw a logical conclusion from presented information, in this case to predict the products of selected chemical reactions when presented with the reactants. As this is conceptual knowledge (knowledge of the interrelationships among the basic elements within a large structure that enable them to function together) In this case, assessments must show that students understand how the chemical properties of the substances and the relationships among the substances determine the products of given reactions, and that the student can represent that reaction in the correct and accepted form.

C-4.3 Analyze the energy changes (endothermic or exothermic) associated with chemical reactions.

Revised Taxonomy Level 4 **<u>Analyze</u> conceptual knowledge**

In physicals science, students

- Summarize characteristics of balanced chemical equations (including conservation of mass and changes in energy in the form of heat –that is, exothermic or endothermic reactions). (PS-4.7)

It is essential for students to

- Show energy changes in chemical reactions (for example)
  - Endothermic reaction
    $2H_2O$ + energy $\longrightarrow$ $2H_2$ + O_2
  - Exothermic reaction
    $2H_2$ + O_2 $\longrightarrow$ $2H_2O$ + energy
- Understand that the "heat of reaction" is the quantity of energy released or absorbed as heat during a chemical reaction.
  Teacher note: "heat of reaction" should be expressed in terms of kJ per mole, so quantitative application of this concept should not be introduced until after students have mastered the mole concept.
- Understand enthalpy as the energy absorbed or released as heat during a chemical reaction at constant pressure
  - Explain the relationship between enthalpy change and the tendency of a reaction to occur.
- Understand that some endothermic reactions may be spontaneous due to an increase in entropy, a measure of the degree of randomness of the particles, such as molecules, in a system.
  - Explain the relationship between entropy change and the tendency of a reaction to occur.
  - Explain the relationship between various conditions and the entropy of the system
    - Temperature
    - Phase
    - Formation of solutions

Assessment

The revised taxonomy verb for this indicator is analyze, which means to "break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose". In this case, students should be able to predict the spontaneity of a chemical reaction based on the heat of reaction and the enthalpy change. Because the indicator is written as <u>conceptual knowledge,</u> assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students understand the conditions that influence both enthalpy and entropy and that both factors play a role on determining the spontaneity of a chemical reaction.

C-4.4 Apply the concept of moles to determine the number of particles of a substance in a chemical reaction, the percent composition of a representative compound, the mass proportions, and the mole-mass relationships.

Revised Taxonomy Level 3.2 B <u>Apply</u> conceptual knowledge

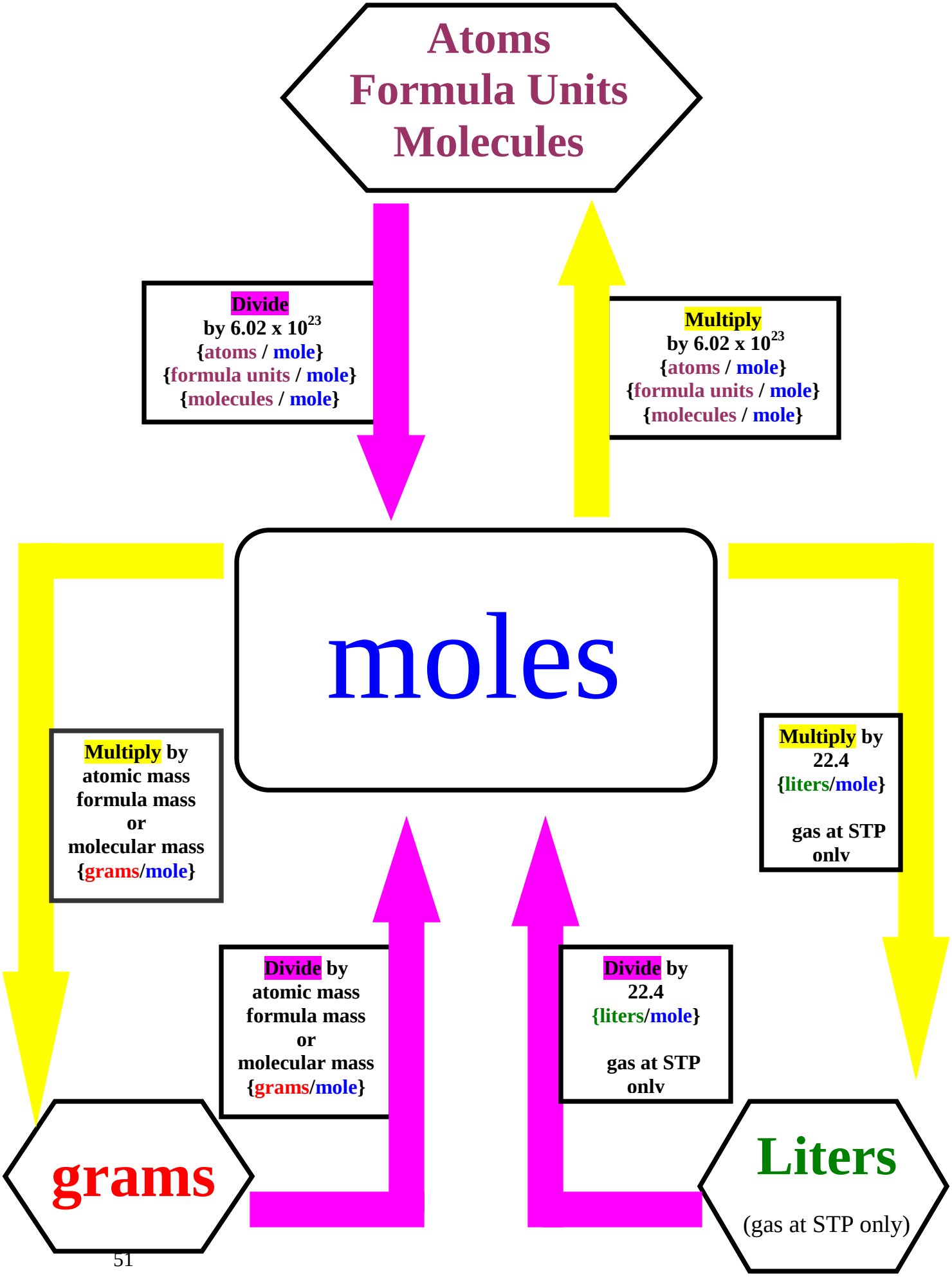
This concept was not addressed in physical science

It is essential for students to

- Understand that the quantity 6.02×10^{23} of any object is defined as a "mole" of the object.
- Understand that the atomic mass of a substance, as found on the periodic table, represents the average mass (in atomic mass units) of the naturally occurring isotopes of the element.
- Understand that the molar mass of a pure substance is the mass (in grams) of one mole of the substance (the molar mass of carbon atoms is the mass (in grams) of one mole of carbon atoms).
- Understand that the molar mass of an element (measured in grams) is numerically equal to the atomic mass of the element (measured in atomic mass units)
- Understand that the formula mass is the term used for ionic substances. It is the sum of the atomic masses of all of the elements contained in one formula unit of an ionic compound.
- Understand that the molecular mass is the term used for molecular compounds. It is the sum of the atomic masses of all of the elements in the molecular formula of the substance.
- Calculate the formula mass or molecular mass of any given compound.
- Use molar mass, formula mass, or molecular mass to convert between mass in grams and amount in moles of a chemical compound. (see mole chart, pg 5)
- Calculate the number of molecules, formula units, or ions in a given molar amount of a chemical compound.
- Calculate the percent composition of a given chemical compound.

Assessment

The revised taxonomy verb for this indicator is <u>implement</u> <u>(apply)</u>, the major focus of assessment will be for students to show that they can "apply a procedure to an unfamiliar task". In this case, to apply the concept of mole theory to determine the mass or number of particles present in a given sample of a substance. Because the indicator is written as <u>conceptual knowledge,</u> assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students can apply their knowledge of the relationship among mass, mole, and particle number quantities to solve novel problems.


Atoms
Formula Units
Molecules
Divide
by 6.02 x 10^23
{atoms / mole}
{formula units / mole}
{molecules / mole}
Multiply
by 6.02 x 10^23
{atoms / mole}
{formula units / mole}
{molecules / mole}
moles
Multiply by
atomic mass
formula mass
or
molecular mass
{grams/mole}
Multiply by
22.4
{liters/mole}
gas at STP
onlv
Divide by
atomic mass
formula mass
or
molecular mass
{grams/mole}
Divide by
22.4
{liters/mole}
gas at STP
onlv
grams
Liters
(gas at STP only)

C-4.5 Predict the percent yield, the mass of excess, and the limiting reagent in chemical reactions.

Revised Taxonomy Level 2.5-B Infer (predict) conceptual understanding

This concept was not addressed in physical science

It is essential for students to

- Perform stoichiometric calculations
  - Mass-mass
  - Limiting reactant
  - Percent yield

Assessment Guidelines

The objective of this indicator is for students to infer (predict) the mass of reactants needed or products that will be produced in a chemical reaction, to determine the quantity in excess and the limiting reactant, and to determine the percent yield in selected reactions. As this is conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together.", in this case, how mass, and mole ratios in a balanced chemical reaction can be used to determine predicted quantities which are needed or are produced during a chemical reaction.

C-4.6 Explain the role of activation energy and the effects of temperature, particle size, stirring, concentration, and catalysts in reaction rates.

Revised Taxonomy Levels 2.7 B Explain conceptual knowledge

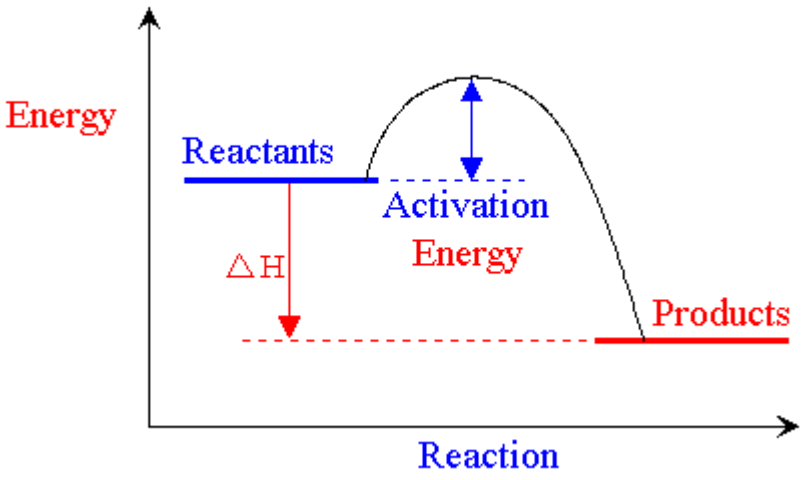
In physical science students

- Explain the effects of temperature, concentration, surface area, and the presence of a catalyst on reaction rates. (PS-4.11)
  - This is addressed in a descriptive manner in physical science

It is essential for students to

- Analyze an energy level diagram

Energy Level Diagram



The change in energy can be plotted against the progress of a reaction, as the reactants turn into products.

- Going from reactants to the top of the curve, you are going up the energy scale.
  - Energy (heat) is being put in to break bonds in the reactants.
  - At the top of the curve, the bonds in the reactants have been broken.
- The amount of energy put in to break these bonds is called the activation energy.
- The activation energy is the minimum amount of energy needed for the reaction to occur.

- Relate activation energy to heat of reaction
  - Going from the top of the curve to the products, you are going down the energy scale.
    - Energy (heat) is given out as bonds form in the products.
  - The reactants are higher up the energy scale than are the products.
  - The amount of energy (heat) you need to put in (the activation energy) is less than the amount of energy (heat) you get out.
  - This is a typical exothermic reaction.
  - The difference in energy levels between the reactants and the products is given the symbol ΔH
    - This is the amount of heat given out (or taken in) during the reaction.
    - For an exothermic reaction, ΔH is negative.
    - For an endothermic reaction, ΔH is positive.
- Analyze the effects of temperature, particle size, stirring, concentration, and catalysts on reaction rates
  - For each factor students should be able to explain, in terms of the kinetic theory, how the factor influences the reaction rate in terms of
    - Collision energy
    - Collision frequency
    - Activation energy

Assessment

The verb, explain means that the major focus of assessment should be for students to "construct a cause and effect model". In this case, assessments will ensure that students can model how each of the factors (temperature, particle size, stirring, concentration, and catalysts) influence the rate of a chemical reaction. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students can construct a cause and effect statement relating each of these factors affects the ability of molecules to break or form bonds.

The following four indicators (4.7 – 4.10) should be selected as appropriate to a particular course for additional content and depth:

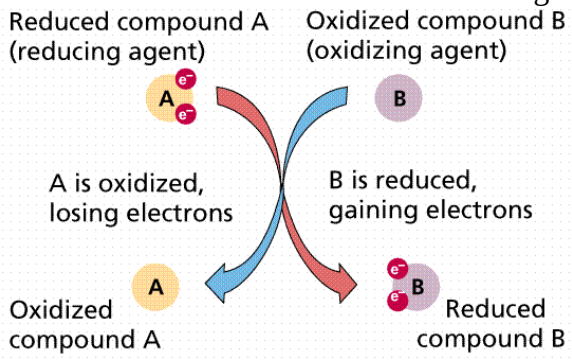
C-4.7 Summarize the oxidation and reduction processes (including oxidizing and reducing agents).

Revised Taxonomy Level 2.4 <u>Summarize</u> conceptual knowledge

This concept was not addressed in physical science

It is essential for students to

- Understand that "oxidation" is defined as the process of losing electrons, "reduction" is defined as process of gaining electrons
  - A substance that is "oxidized" has lost electrons
  - A substance that is "reduced" has gained electrons
  - When a substance is oxidized, it "gives" electrons to another substance, causing that substance to gain electrons or be reduced.
    - A substance that causes another substance to be reduced is called a "reducing agent"
    - Any substance that is oxidized is a reducing agent
  - When a substance is reduced, it "takes" electrons from another substance, causing that substance to lose electrons or be oxidized.
    - A substance that causes another substance to be oxidized is called an "oxidizing agent"
    - Any substance that is reduced is called an oxidizing agent



  - Cite examples of oxidation and reduction reactions

Assessment

The revised taxonomy verb, summarize means "to abstract a general theme or major point" For this indicator, the major focus of assessment should be to insure that students have a deep conceptual understanding of the processes of oxidation and reduction. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together. In this case, that students understand how each substance in the reaction is changed during an oxidation/reduction reaction.

C-4.8 Illustrate the uses of electrochemistry (including electrolytic cells, voltaic cells, and the production of metals from ore by electrolysis). (additional content/depth)

Revised Taxonomy Level 2.2-B Exemplify (illustrate) conceptual knowledge

Students did not address this concept in physical science

It is essential for students to

- Identify, balance and explain simple oxidation-reduction chemical reactions, for example

  $CuSO_4 + Mg \rightarrow MgSO_4 + Cu$

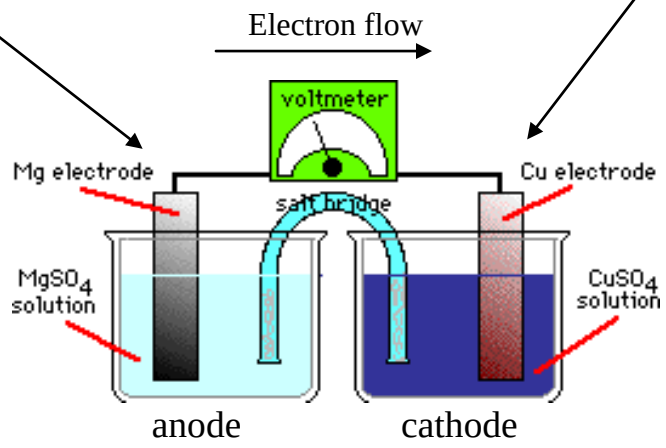
  - Assign oxidation numbers to all elements in the reaction

    $CuSO_4 + Mg \rightarrow MgSO_4 + Cu$

    Cu +2 Cu 0
    O -2 O -2
    S +6 S +6
    Mg 0 Mg +2
  - Understand that copper went from +2 to 0, it became more negative, so it gained electrons.
    - Copper is reduced.
  - Understand that magnesium went from 0 to +2, it became more positive, so it lost electrons.
    - Magnesium was oxidized.
  - Write the half reactions for simple oxidation-reduction reactions:
    - Reduction: $Cu^{+2} + 2e^- \text{----> } Cu^0$
      Oxidation: $Mg^0 \text{----> } Mg^{+2} + 2e^-$
  - Understand terms which are used to describe voltaic cells
    - A voltaic cell is an electrochemical cell in which the redox reaction occurs spontaneously and produces electrical energy.
    - The electrode is a conductor used to establish electrical contact with a nonmetallic part of a circuit (such as the electrolytes)
    - The anode is the electrode where oxidation takes place.
    - The cathode is the electrode where reduction takes place.
    - The salt bridge (or porous barrier) allows the reaction to continue because it
      - allows anions ($S0_4^{-2}$ from the $CuSO_4$ solution) to move toward the anode to replace the negatively charged electrons that are moving away during oxidation.
      - allows cations (Mg^{+2} from the Mg SO_4 solution) to move toward the cathode as to balance the negative charge resulting from reduction.
  - Diagram, label and describe the operation of a voltaic cell.

Mg loses electrons at the Mg electrode. The electrons travel through the external wire to the Cu electrode.

Example of a Voltaic Cell



Electrons, which have traveled through the external wire from the Mg electrode, enter the Cu electrode.

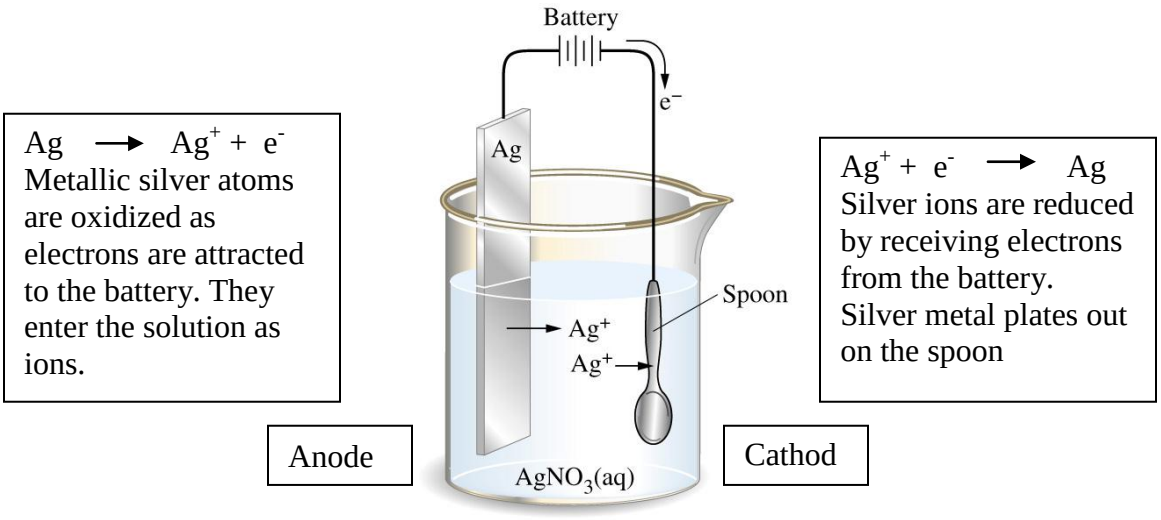
The Mg^{+2} ions that are formed when Mg atoms lose electrons enter the $MgSO_4$ solution.

Cu^{+2} ions from the solution gain electrons which have traveled through the external wire, forming Cu metal which plates out on the Cu electrode.

- The reaction in this voltaic cell requires that 2 electrons are transferred from the Mg to the Cu.

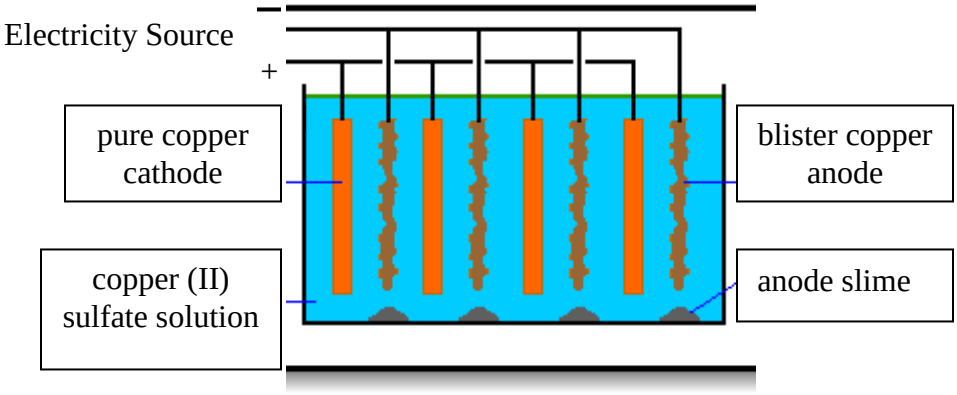
- Use standard reduction potentials to calculate voltage of standard voltaic cells
- Understand that an electrolytic cell is one in which electrical energy is required to produce a redox reaction and bring about a chemical change in an electrochemical cell.
- Diagram, label and describe the operation of an electrolysis cell for electroplating (an example of an electrolytic cell

Electrolysis cell for electroplating



❖ Diagram, label and describe the production of metals from ore by electrolysis

Electro-refining of copper



- When copper is first obtained by reduction of its ores, it is cast as impure slabs or ingots, called blister copper.
- Blister copper is used for anodes
- Copper (II) sulfate is used as electrolyte.
- Initially, the cathodes consist of thin sheets of pure copper.
- During electrolysis, Cu metal in the blister copper receives electrons from the source of electricity and is reduced to Cu^{+2}. The Cu^{+2} ions pass into solution from the anodes.

- Impurities in the anode, normally silver, gold and platinum are left behind. The impurities, which are collectively called anode slime, sink to the bottom of the cell.
- The anode reaction is
  - $Cu_{(s)} \longrightarrow Cu^{+2}_{(aq)} + 2e^-$

- At the cathode, copper (II) ions combine with electrons which are (from the source of electricity) forming Cu metal. The pure copper sheet becomes coated with an increasingly thick layer of very pure copper:
  - The cathode reaction is
    - $Cu^{+2}_{(aq)} + 2e^- \longrightarrow Cu_{(s)}$

Assessment

The verb exemplify (illustrate) means to find a specific example or illustration of a concept or principle, therefore the major focus of assessment will be for students to give examples that show that they understand the functioning of electrolytic cells, voltaic cells, and the production of metals from ore by electrolysis. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together. In this case, that students understand how each part of the various cells function to produce the desired condition.

C-4.9 Summarize the concept of chemical equilibrium and Le Châtelier's principle. (additional content/depth)

Revised Taxonomy Level 2.4 <u>Summarize</u> conceptual knowledge

Students did not address this concept in physical science

It is essential for students to

- Understand that equilibrium is a dynamic condition in which two opposing changes occur at equal rates in a closed system.
- Illustrate that equilibrium as it applies to
  - Reversible chemical reactions
  - Solubility
  - Phase change
- Understand and apply La Châtelier's Principle in reference to the following stresses
  - A change in concentration
  - A change in temperature
  - A change in pressure

Assessment

The revised taxonomy verb, summarize means "to abstract a general theme or major point" For this indicator, the major focus of assessment should be to insure that students have a conceptual understanding of systems in equilibrium and how they are affected by stress as described by La Châtelier's Principle. Students should be able to predict what will happen to a system which is stressed. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together. In this case, students can explain in terms of the kinetic theory and according to principles of chemical reaction the effect that each of the three variables (concentration, temperature, and pressure) have on a given system.

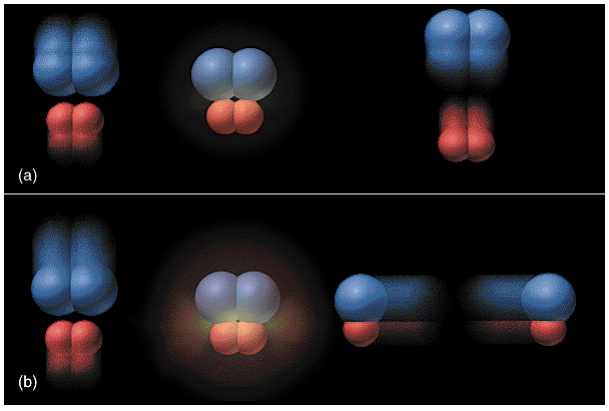
C-4.10 Explain the role of collision frequency, the energy of collisions, and the orientation of molecules in reaction rates. (additional content/depth)

Revised Taxonomy Levels 2.7 B <u>Explain</u> conceptual knowledge

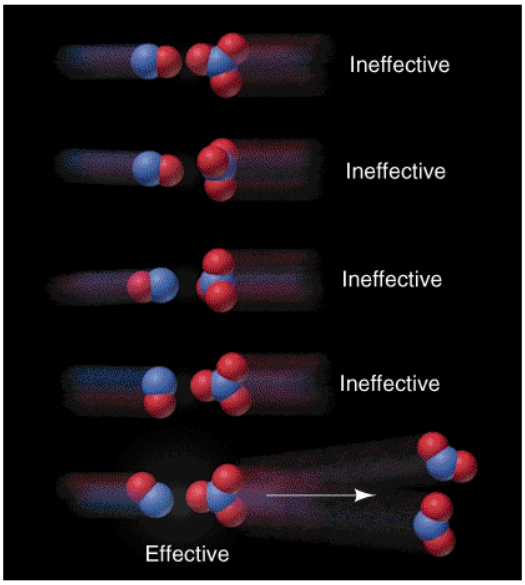
This concept was not addressed in physical science

It is essential for students to

- Understand that the more collisions among the particles in a sample of reacting substances, the greater the reaction rate.
  - Explain how various factors can influence collision frequency
- Understand that only collisions which occur between particles with enough energy to react result in the formation of products.
  - In diagram (a) the molecules do not have enough kinetic energy to react
  - In diagram (b) the molecules do have enough energy so the collision results in a reaction.



- Understand that only collisions which occur between particles in the correct orientation result in the particles reacting to form products.
  - In the diagram below, only the last illustration results in a chemical reaction.



Assessment

- The verb, explain means that the major focus of assessment should be for students to "construct a cause and effect model". In this case, assessments will ensure that students can model how collision frequency, collision energy and the orientation of molecules influence reaction rate. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students can construct a cause and effect statement relating how each of these factors affect the rate of a chemical reaction in terms of kinetic theory.

Standard C-5: The student will demonstrate an understanding of the structure and behavior of the different phases of matter.

Supporting Content Web Sites

SparkNotes
http://www.sparknotes.com/chemistry/
This website contains concise descriptions of chemistry principles. Also includes sample problems.
All C-5 indicators

Science Line
http://www.wpbschoolhouse.btinternet.co.uk/page03/3_52states/3_52statesQ.htm ,
http://www.wpbschoolhouse.btinternet.co.uk/page03/3_51energy/3_51energyQ.htm
Multiple choice questions on solids, liquids and gases.
C-5.2, C-5.4, C-5.5

Homework High
http://www.channel4.com/learning/microsites/H/homeworkhigh/science/index.jsp
This website provides answers to general physics questions.
All indicators for C-5

American Chemical Society, chemistry.org
http://center.acs.org/education/olympiad/2003/practice_test/index.html
On-line practice tests on states of matter and other chemistry subjects.
All indicators for C-5

ChemTeam
http://dbhs.wvusd.k12.ca.us/webdocs/ChemTeamIndex.html
The ChemTeam provides study resources in all standard topics for students in high school and Advanced Placement chemistry.
All indicators for C-5

Rader's CHEM4KIDS
http://www.chem4kids.com/
This website provides students with supporting material for most general chemistry topics. It is well organized and easy to follow.
All indicators for C-5

Visualization and Problem Solving for General Chemistry (Purdue University)
http://www.chem.purdue.edu/gchelp/
This website contains very clear descriptions of chemistry topics.
All indicators for C-5

Gas Laws An Internet WebQuest on Chemistry
http://www.kn.att.com/wired/fil/pages/webchemistrga.html

This is a WebQuest that takes students through gas law calculations and theory.
C-5.2, C-5.3, C-5.7

Virtual ChemBook
http://www.elmhurst.edu/%7Echm/vchembook/index.html
This site has very clear explanations of most general chemistry topics.
All indicators for C-5

Advanced Placement Digital Library (Rice University)
http://apdl.rice.edu/DesktopDefault.aspx?tabindex=4&tabid=34
This site provides excellent resources for all general chemistry topics. There are activities, tutorials, videos, virtual and real labs, and so much more.
All indicators for C-5

Suggested Literature

Sacks, Oliver. (2002). *Uncle Tungsten: Memories of a Chemical Boyhood*. New York:Vintage.
ISBN: 0375704043
Oliver Sacks uses stories of his childhood to describe applications of chemistry and the history of chemistry. There are many applications of the concept of gases, chemical processes, and energy changes.
C-5.2, C-5.4, C-5.5, C-5.8, C-5.9

Schwarcz, Dr. Joe. (2002). *The Genie in the Bottle: 67 All-New Commentaries on the Fascinating Chemistry of Everyday Life*. Ontario:Owl Books.
ISBN: 0805071385
Dr. Schwarcz uses really-life examples to describe applications of chemistry. The focus is mainly on food and health sciences. There are many applications of phases of matter, energy changes, and chemical processes.
C-5.2, C-5.4, C-5.5, C-5.8, C-5.9

Burreson, Jay and Couteur, Penny Le. (2004) *Napoleon's Buttons* (pb reprint). New York:Tarcher.
ISBN: 1585423319
Napoleon's Buttons is the fascinating account of seventeen groups of molecules that have greatly influenced the course of history. There are many applications of phases of matter, energy changes, and chemical processes.
C-5.2, C-5.4, C-5.5, C-5.8, C-5.9

Gonick, Larry. (2005) *The Cartoon Guide to Chemistry*. New York:Collins.
ISBN: 0060936770
This book is a refreshingly humorous but thorough ancillary guide to general chemistry. It covers all areas of general chemistry.
All indicators for C-5

Wertheim, Jane. (2000). *Illustrated Dictionary of Chemistry*. London:Usborne Books.
ISBN: 0746037945
Excellent resource book for all topics in general chemistry.
All indicators for C-5

Houk, Clifford C., and Post, Richard. (1996*). Chemistry: Concepts and Problems: A Self-Teaching Guide*. New Jersey: Wiley.
ISBN: 0471121207
This book has easy to follow examples and explanations of chemistry principles. It covers all general chemistry topics.
All indicators for C-5

Moore, John T. (2002). *Chemistry For Dummies*. New Jersey: For Dummies.
ISBN: 0764554301
This book has easy to follow examples and explanations of all general chemistry topics.
All indicators for C-5

Asimov, Isaac. (1979). *A Short History of Chemistry*. Westport, CT:Greenwood Press Reprint.
ISBN: 0313207690
From the use of metals by prehistoric man to the alchemical experiments of medieval and Renaissance man to the complex chemical skills of contemporary man, Asimov traces the development of this building block of our technological world. This book incorporates knowledge of chemical processes, phases of matter, density, and energy changes.
C-5.1, C-5.5, C-5.6, C-5.9

Cobb, Cathy, and Fetterolf, Monty L. (2005). *The Joy of Chemistry: The Amazing Science of Familiar Things*. New York:Prometheus Books.
ISBN: 1591022312
This book uses real-life examples to explain the science of chemistry. Most general chemistry topics are covered.
All indicators for C-5

Williams, Linda. (2003). *Chemistry Demystified*. New York:McGraw-Hill Professional.
ISBN: 0071410112
This book supports the learning of most general chemistry topics. It uses a step-by-step method to help students understand concepts.
All indicators for C-5

Suggested Steamline Video Resources

Elements of Chemistry: Gases, Liquids, and Solids
All segments
ETV Streamline SC
This program reviews the different gas laws as well as examining the characteristics of substances and elements when they are liquids and solids.
All segments are applicable. 20 minute video.
C-5.1, C-5.2, C-5.3, C-5.7

Physical Science Series: Phases of Matter
All segments
ETV Streamline SC
Through interesting visual examples of the many uses of water, students learn about viscosity, elasticity, solids, liquids, gases, phase changes, Boyle's Law, Charles' Law, vaporization, sublimation, melting, freezing, and condensation, as well as many other concepts.
All segments are applicable. 18 minute video.
C-5.2, C-5.3, C-5.4, C-5.5, C-5.7

Chemistry Connections: Kinetic and Potential Energy Changes During Changes to States of Matter
All segments
ETV Streamline SC
Examples and graphs that illustrate energy changes during phase changes.
All segments are applicable. 29 minute video.
C-5.4, C-5.5

Chemistry Connections: The Enthalpy of Phase Changes

All segments
ETV Streamline SC
Examples and graphs that illustrate energy changes during phase changes. The molar enthalpies for condensation and fusion of water are determined calorimetrically, and various enthalpy change problems are solved
All segments are applicable. 29 minute video.
C-5.4, C-5.5

Common Properties of Matter: Atoms, Elements, and States
A Closer Look at the States of Matter (04:35) (segment 4)
States of Matter (03:10) (segment 5)
ETV Streamline SC
Video gives a description of the states of matter, as well as discussing density of matter.
A Closer Look at the States of Matter (04:35) (segment 4)
States of Matter (03:10) (segment 5)
C-5.1

Simply Science: Water's Physical Properties

All segments
ETV Streamline SC
Properties of water are discussed and demonstrated. Also shows how phase changes occur. 5. All segments are applicable. 27 minute video.
C-5.1, C-5.4, C-5.5

Simply Science: Water's Structure
The Shape of Water (03:28) (segment 4)
ETV Streamline SC
Video describes the shape of a water molecules and describes the intermolecular forces between water molecules.
The Shape of Water (03:28) (segment 4)
C-5.1

Magic School Bus Goes on Air, The
All segments
ETV Streamline SC
Mrs. Frizzle and her students learn about all about air, including how air behaves (as a gas).
All segments are applicable. 27 minute video.
C-5.2

Chemistry Connections: Quantitative Analysis Using Redox Titration
All segments
ETV Streamline SC
Students learn about redox reactions and use a redox titration to quantitatively analyze a sample.
All segments are applicable. 29 minute video.
C-5.8

Biology of Water, The: Water: A Miraculous Substance (The Properties of Water and the Development of Life)
Water: General Physical and Chemical Properties (06:38) Segment 2
Heat Capacity: Climatic Effects (00:48) Segment 3
Latent Heat: Changes of State and Heat Effects (01:23) Segment 4
ETV Streamline SC
This program examines the unique physical and chemical properties of water, including molecular structure, solvent capabilities, changes of physical state, surface tension, heat capacity, and latent heat.
Water: General Physical and Chemical Properties (06:38) Segment 2
Heat Capacity: Climatic Effects (00:48) Segment 3
Latent Heat: Changes of State and Heat Effects (01:23) Segment 4
C-5.1, C-5.5

Physical Science: States of Matter

All segments
ETV Streamline SC
Video uses clear examples of each state of matter. Also addresses properties of each state.
All segments are applicable. 20 minute video.
C-5.1, C-5.2, C-5.5, C-5.7

Career Connections

HVAC technician
HVAC technicians install and maintain heating and air conditioning systems. There is an obvious need for this career, especially here in the South. HVAC technicians go through training that can take up to two years. They must understand concepts of gases, energy changes, phase changes, and gas pressure.

Chemical engineer

Chemical engineers can specialize in many areas. If they work in an industrial setting, they would need to know about gases, their properties, and the effects of high and low pressure on gases. They would also have to know about phase and energy changes.

Quality control technician

Quality control technicians often work in industrial or consumer settings. Their job is to analyze products before the product is shipped to the consumer. They will test for product purity, density, and overall quality.

Meteorologist
Meteorologists analyze atmospheric air patterns to help predict the weather. They must understand the properties of gases and pressure. They must also understand the interrelated effects of temperature, pressure, and energy changes.

C-5.1 Explain the effects of the intermolecular forces on the different phases of matter.

Revised Taxonomy Levels 2.7 B <u>Explain</u> conceptual knowledge

Students did not address this concept in physical science

It is essential for students to

- Diagram, describe, and give examples of the following intermolecular forces
  - Dipole-dipole attraction
    - Hydrogen bonding
  - London dispersion forces
- Compare intermolecular forces (dipole-dipole interaction, and London dispersion forces) and ionic bonds, covalent bonds, and metallic bonds in terms of
  - Nature of the attraction
  - type of substance
  - structural unit
  - examples
  - typical properties

Type of Substance	Structural Unit	Inter-particle Force	Substance	Melting Point (1atm, ˚C)	Boiling Point (1atm, ˚C)
Non-polar Covalent (molecular)	molecule	London Dispersion Forces	H_2	-259	-253
			O_2	-218	-183
			CH_4	-182	-164
			CCl_4	-23	77
			C_6H_6	6	80
Polar Covalent (molecular)	molecule	Dipole-dipole interaction	H_2O	0	100
			H_2S		-61
			HCl		-85
			NH_3	-78	-33
Ionic	ion	Ionic bonds	NaCl	801	1413
			MgF_2	1266	2239
Metallic	atom	Metallic bonding	Cu	1083	2567
			Fe	1535	2750
			Hg	-39	357
			W	3410	5660
Covalent Network	atom	Covalent bonds	$(SiO_6)_x$	1610	2230
			C_x (diamond)	3500	3930

- Use a chart, such as the one above to compare the intermolecular forces present in substances with high, low, and moderate melting and boiling points.

- Discuss other factors, (in addition to the nature of the intermolecular force) which affect the melting and boiling point of a substance.

Assessment

The verb, explain means that the major focus of assessment should be for students to "construct a cause and effect model". In this case, assessments will ensure that students can model how intermolecular forces influence the melting point and boiling point of various types of substance. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students can construct a cause and effect statement relating how the intermolecular forces, in the context of other factors, determine the properties of a substance.

C-5.2 Explain the behaviors of gas; the relationship among pressure, volume, and temperature; and the significance of the Kelvin (absolute temperature) scale, using the kinetic-molecular theory as a model.

Revised Taxonomy Levels 2.7 B Explain conceptual knowledge

Students did not address this concept in physical science

It is essential for students to

- Use the Kinetic Molecular Theory as a model to explain the relationship between, pressure, and volume in a gas sample.
- Explain the significance of the absolute temperature scale in terms of the Kinetic Molecular Theory.
  - Explain the relationship between temperature and average kinetic energy.

Assessment

The verb, explain means that the major focus of assessment should be for students to "construct a cause and effect model". In this case, assessments will ensure that students can use the Kinetic Molecular Theory as a model for the behavior of gasses. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students can construct a cause and effect statement relating how each variable, (pressure, volume, and temperature), effects each of the others.

C-5.3 Apply the gas laws to problems concerning changes in pressure, volume, or temperature (including Charles's law, Boyle's law, and the combined gas law).

Revised Taxonomy Level 3.2 C_A <u>Apply</u> procedural knowledge

This concept was not addressed in physical science

It is essential for students to

- Explain Charles' law and Boyle's laws in terms of the kinetic molecular theory
- Solve gas law problems concerning changes in gas pressure, volume, or temperature.

Assessment

The revised taxonomy verb for this indicator is <u>implement</u> <u>(apply)</u> the major focus of assessment will be for students to show that they can "apply a procedure to an unfamiliar task". The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods" In this case the procedure for solving gas law problems using Charles' and Boyle's laws. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat problems which are familiar. This requires that students have a conceptual understanding of gasses in terms of the Kinetic Molecular Theory.

C-5.4 Illustrate and interpret heating and cooling curves (including how boiling and melting points can be identified and how boiling points vary with changes in pressure).

Revised Taxonomy Level 2.2-B Exemplify (illustrate) conceptual knowledge

In physical science students

- Explain the process of phase change in terms of temperature, heat transfer, and particle arrangement (PS-3.7)
  - Physical science students explain phase change in terms of the Kinetic Molecular Theory
  - Physical science students explain why temperature vs. time graphs show constant temperature during phase change.

It is essential for students to

- Define phase changes in terms of kinetic energy of the particles, heat transfer, and particle orientation and arrangement.
  - melting
  - boiling
  - condensation
  - freezing
  - sublimation
- Differentiate the processes of evaporation and boiling
- Differentiate the terms gas and vapor
- Explain how atmospheric pressure and vapor pressure affect the boiling point of a substance
  - Analyze a phase diagram (temperature vs. pressure)
    - Explain triple point
    - Critical point
- Analyze a graph of temperature vs time which illustrates the heating or cooling of a substance over the range of phase change.
  - Explain the shape of the graph in terms of kinetic energy, potential energy, and heat transfer

- **Assessment**

The verb exemplify (illustrate) means to find a specific example or illustration of a concept or principle, therefore the major focus of assessment will be for students to give examples that show that they understand phase change in terms of the Kinetic Molecular Theory. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together. In this case, that students understand how pressure and temperature, and heat flow affect the kinetic energy, potential energy, and orientation of the particles of a substance.

The following five indicators (5.5 -5.9) should be selected as appropriate to a particular course for additional content and depth:

C-5.5 Analyze the energy changes involved in calorimetry by using the law of conservation of energy as it applies to temperature, heat, and phase changes (including the use of the formulas $q = mc\Delta T$ [temperature change] and $q = mLv$ and $q = mLf$ [phase change] to solve calorimetry problems). (additional content/depth)

Revised Taxonomy Level 4 <u>Analyze</u> conceptual knowledge

Students did not address this concept in physical science

It is essential for students to

- Differentiate between the terms temperature and heat in terms of the Kinetic Molecular Theory
- Understand the terms
  - gram specific heat
  - molar specific heat
  - heat of fusion
  - heat of vaporization
- Solve problems involving the heat required (or released) when a substance undergoes any combination of temperature and phase change.
- Solve problems involving the heat transferred from one substance to another when the two substances reach thermal equilibrium.
  - Determine the temperature change and the phase of each substance upon reaching equlibrium.

Assessment

The revised taxonomy verb for this indicator is analyze, which means to "break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose". In this case, students should be able to consider a the energy changes that a substance or system of substances must experience in order to go from one phase and/or temperature to another. Because the indicator is written as <u>conceptual knowledge,</u> assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together."

C-5.6 Use density to determine the mass, volume, or number of particles of a gas in a chemical reaction.

Revised Taxonomy Level 3.2 C_A Apply (use) procedural knowledge

Students did not address this concept in physical science

It is essential for students to

- Understand the volume of a mole of any gas at STP is 22.4 l/mole
  - Use the combined gas law equation to find the volume of a gas under various conditions when given the volume at STP
- Use the molar volume of a gas to perform stoichiometric calculations for gasses.
  - Volume to volume
  - Mass to volume
  - Moles to volume
- Understand the quantitative relationship between density and molecular weight.
  - molecular weight divided by 22.4 liters per mole = density of a gas at STP

Assessment

The revised taxonomy verb for this indicator is implement (use), the major focus of assessment will be for students to show that they can "apply a procedure to an unfamiliar task". The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods" In this case the procedure for solving stoichiometric calculations for chemical reactions involving gasses. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat problems which are familiar. This requires that students have a conceptual understanding of the way that pressure and temperature affect the volume and mass of a gas.

C-5.7 Apply the ideal gas law (pV = nRT) to solve problems.

Revised Taxonomy Level 3.2 C_A <u>Apply</u> procedural knowledge

Students did not address this concept in physical science

It is essential for students to

- Explain the ideal gas law in terms of the Kinetic Molecular Theory
- Understand the ideal gas constant, R has various forms and must be consistent with the units for the other variables.

Unit of R	Numerical value of R	Unit of P	Unit of V	Unit of T	Unit of n
$\frac{L \bullet mmHg}{mol \bullet K}$	**62.4**	**mm Hg**	**L**	**K**	**mol**
$\frac{L \bullet atm}{mol \bullet K}$	**0.0821**	**atm**	**L**	**K**	**mol**
$\frac{J}{mol \bullet K}$	**8.314***	**Pa**	**m^3**	**K**	**mol**
$\frac{L \bullet kPa}{mol \bullet K}$	**8.314**	**kPa**	**L**	**K**	**mol**
***note:** $1\ L \bullet atm = 101.325$ J; 1J = 1 $Pa \bullet m^3$					

- Use the ideal gas law equation to find pressure, volume, temperature, or number of moles.

Assessment

The revised taxonomy verb for this indicator is <u>implement</u> <u>(apply)</u>, the major focus of assessment will be for students to show that they can "apply a procedure to an unfamiliar task". The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods" In this case the procedure for solving problems using the ideal gas law equation. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat problems which are familiar. This requires that students have a conceptual understanding of the ideal gas law.

C-5.8 Analyze a product for purity by following the appropriate assay procedures.

Revised Taxonomy Level 4 <u>Analyze</u> conceptual knowledge

Students did not address this concept in physical science

It is essential for students to

- Assay product purity using simple analytical chemical procedures.

Assessment

The revised taxonomy verb for this indicator is analyze which means to "break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose". In this case, students should be able to analyze a chemical process and account for loss due to loss and error. Because the indicator is written as <u>conceptual knowledge,</u> assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students understand the reasons for the difference in the expected and actual values.

C-5.9 Analyze a chemical process to account for the weight of all reagents and solvents by following the appropriate material balance procedures.

Revised Taxonomy Level 4 Analyze conceptual knowledge

Students did not address this concept in physical science

It is essential for students to

- Perform a material balance (i.e. account for the weights of all reagents and solvents in a chemical process) using simulated industrial data.

Assessment

The revised taxonomy verb for this indicator is analyze, which means to "break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose". In this case, students should be able to analyze a chemical process and account for loss due to loss and error. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students understand the reasons for the difference in the expected and actual values.

Standard C-6: The student will demonstrate an understanding of the nature and properties of various types of chemical solutions.

Supporting Content Web Sites

SparkNotes
http://www.sparknotes.com/chemistry/
This website contains concise descriptions of chemistry principles. Also includes sample problems.
All indicators for C-6

Science Line
http://www.wpbschoolhouse.btinternet.co.uk/page03/AcidsBasesSalts/AcidBaseQmcF.htm
Multiple choice questions related to calculating pH and pOH.
C-6.8

Homework High
http://www.channel4.com/learning/microsites/H/homeworkhigh/science/index.jsp
This website provides answers to general chemistry questions.
All indicators for C-6

American Chemical Society, chemistry.org
http://center.acs.org/education/olympiad/2003/practice_test/index.html
On-line practice tests on solutions and other chemistry subjects.
All indicators for C-6

ChemTeam
http://dbhs.wvusd.k12.ca.us/webdocs/ChemTeamIndex.html
The ChemTeam provides study resources in all standard topics for students in high school and Advanced Placement chemistry.
All indicators for C-6

Rader's CHEM4KIDS
http://www.chem4kids.com/
This website provides students with supporting material for most general chemistry topics. It is well organized and easy to follow.
All indicators for C-6

Visualization and Problem Solving for General Chemistry (Purdue University)
http://www.chem.purdue.edu/gchelp/
This website contains very clear descriptions of chemistry topics.
All indicators for C-6

Virtual ChemBook

http://www.elmhurst.edu/%7Echm/vchembook/index.html
This site has very clear explanations of most general chemistry topics.
All indicators for C-6

Advanced Placement Digital Library (Rice University)
http://apdl.rice.edu/DesktopDefault.aspx?tabindex=4&tabid=34
This site provides excellent resources for all general chemistry topics. There are activities, tutorials, videos, virtual and real labs, and so much more.
All indicators for C-6

The ChemCollective: For Students
http://www.chemcollective.org/students.php
This site uses Applets to allow students to complete virtual labs and other activities.
All indicators for C-6

Suggested Literature

Sacks, Oliver. (2002). *Uncle Tungsten: Memories of a Chemical Boyhood*. New York:Vintage.
ISBN: 0375704043
Oliver Sacks uses stories of his childhood to describe applications of chemistry and the history of chemistry. There are many applications of the solutions, acids and bases, and mixtures.
C-6.2, C-6.5, C-6.7, C-6.11

Schwarcz, Dr. Joe. (2002). *The Genie in the Bottle: 67 All-New Commentaries on the Fascinating Chemistry of Everyday Life*. Ontario:Owl Books.
ISBN: 0805071385
Dr. Schwarcz uses really-life examples to describe applications of chemistry. The focus is mainly on food and health sciences. There are many applications of solutions, mixtures, acids and bases.
C-6.2, C-6.5, C-6.7, C-6.11

Burreson, Jay and Couteur, Penny Le. (2004) *Napoleon's Buttons* (pb reprint). New York:Tarcher.
ISBN: 1585423319
Napoleon's Buttons is the fascinating account of seventeen groups of molecules that have greatly influenced the course of history. There are many applications of solutions, mixtures, acids and bases.
C-6.2, C-6.2, C-6.5, C-6.7, C-6.11

Gonick, Larry. (2005) *The Cartoon Guide to Chemistry*. New York:Collins.
ISBN: 0060936770
This book is a refreshingly humorous but thorough ancillary guide to general chemistry. It covers all areas of general chemistry.
All indicators for C-6

Wertheim, Jane. (2000). *Illustrated Dictionary of Chemistry*. London:Usborne Books.
ISBN: 0746037945
Excellent resource book for all topics in general chemistry.
All indicators for C-6

Houk, Clifford C., and Post, Richard. (1996*). Chemistry: Concepts and Problems: A Self-Teaching Guide*. New Jersey: Wiley.
ISBN: 0471121207
This book has easy to follow examples and explanations of chemistry principles. It covers all general chemistry topics.
All indicators for C-6

Moore, John T. (2002). *Chemistry For Dummies.* New Jersey: For Dummies.
ISBN: 0764554301
This book has easy to follow examples and explanations of all general chemistry topics.
All indicators for C-6

Asimov, Isaac. (1979). *A Short History of Chemistry*. Westport, CT:Greenwood Press Reprint.
ISBN: 0313207690
From the use of metals by prehistoric man to the alchemical experiments of medieval and Renaissance man to the complex chemical skills of contemporary man, Asimov traces the development of this building block of our technological world. There are many applications of solutions, mixtures, acids and bases.
C-6.2, C-6.2, C-6.5, C-6.7, C-6.11

Cobb, Cathy, and Fetterolf, Monty L. (2005). *The Joy of Chemistry: The Amazing Science of Familiar Things*. New York:Prometheus Books.
ISBN: 1591022312
This book uses real-life examples to explain the science of chemistry. Most general chemistry topics are covered.
All indicators for C-6

Williams, Linda. (2003). *Chemistry Demystified*. New York:McGraw-Hill Professional.
ISBN: 0071410112
This book supports the learning of most general chemistry topics. It uses a step-by-step method to help students understand concepts.
All indicators for C-6

Suggested Steamline Video Resources

Elements of Chemistry: Acids, Bases, and Salts

All segments
ETV Streamline SC
Video gives descriptions and examples of acids and bases. Includes explanation of pH.
All segments are applicable. 20 minute video.
C-6.6**,** C-6.7, C-6.8

Chemistry Connections: Acids and Bases Defined
All segments
ETV Streamline SC
Video gives basic descriptions of acids and bases. Also gives definitions.
All segments are applicable. 20 minute video.
C-6.6, C-6.7, C-6.8

Simply Science: Water: Highway of Life
All segments
ETV Streamline SC
4. brief description
All segments are applicable. 27 minute video.
C-6.1, C-6.2

Simply Science: Combustion and Replacement Reactions
All segments
ETV Streamline SC
Video focuses on types of reactions, including precipitation reactions.
All segments apply. 27 minute video.
C-6.2, C-6.12

Chemistry Connections: Acid-Base Titrations and Concentration Calculations

All segments
ETV Streamline SC
Students in video work through an analysis of household ammonia using a known acid as titrant.
All segments are applicable. 29 minute video.
C-6.4, C-6.9

Physical Science Series: Mixtures and Solutions

Solutions (01:55) (segment 7)
Solubility (04:15) (segment 8)
ETV Streamline SC
Video shows the creation of solutions and consider the concepts of solubility and rate of dissolving. The following terminology and concepts relating to solutions are addressed: homogeneous and heterogeneous mixtures, solute, solvent, saturated solutions, and unsaturated solutions.

Solutions (01:55) (segment 7)
Solubility (04:15) (segment 8) C-6.1, C-6.2

Chemistry Connections: Explaining the pH/pOH Scale

All segments
ETV Streamline SC
Reveals that the pH scale is an easy way to express hydrogen ion concentration. Provides a definition of pH and shows how it is calculated. Explains a pH/pOH scale and observes the mathematical relationship between pH and pOH.
All segments are applicable. 29 minute video.
C-6.6, C-6.8

Science Investigations Physical Science: Investigating Chemical Reactions

Solutions (06:14)
Solutions: Bees and the Concentration of Sugar in Honey (02:03)
Solutions: The Concentration of Sucrose in Maple Syrup (04:11)
ETV Streamline SC
Video gives real-life examples of solutions and their concentrations.
Solutions (06:14)
Solutions: Bees and the Concentration of Sugar in Honey (02:03)
Solutions: The Concentration of Sucrose in Maple Syrup (04:11)
C-6.1, C-6.4

Physical Science: Chemistry

The Chemistry of Crime Solving (04:25) (segment 2)
ETV Streamline SC
Video discusses the use of chemistry in forensics. Solutions must be separated to be analyzed.
The Chemistry of Crime Solving (04:25) (segment 2)
C-6.11

Life Science: Forensics
All segments
ETV Streamline SC
Video discusses forensics and how chemistry is applied in this field. Solutions must be separated to be analyzed.
All segments are applicable. 20 minute video.
C-6.1, C-6.11, C-6.15

Career Connections

Forensic chemists

"Forensic chemists apply knowledge from diverse disciplines such as chemistry, biology, materials science, and genetics to the analysis of evidence found at crime scenes or on/in the bodies of crime suspects. The field is a combination of criminalistics and analytical toxicology. Criminalistics is the qualitative examination of evidence using methods such as microscopy and spot testing, whereas analytical toxicology looks for evidence in body fluids through a range of instrumental techniques from optical methods (UV, infrared, X-ray) to separations analyses (gas chromatography, HPLC, and thin-layer chromatography). Mass spectrometry is also frequently used since it provides the strongest evidence in court"
(http://www.chemistry.org/portal/a/c/s/1/resources?id=171b0f1254ac11d7ecbe6ed9fe800100)

Laboratory Technician

Clinical laboratory testing is crucial to detecting and diagnosing diseases. Laboratory technicians perform most of these tests. These technicians examine and analyze body fluids, tissues and cells. They look for bacteria, parasites and other microorganisms. They analyze the chemical content of fluids, match blood for transfusions and test for drug levels in the blood to show how a patient is responding to treatment.
People in this field use automated equipment and sophisticated, expensive instruments capable of performing a number of tests simultaneously. They also use other lab equipment, including microscopes and cell counters.
Lab technicians also maintain glassware, instruments, logs, and record books. They also troubleshoot and help with special projects."
(http://jobprofiles.monster.com/Content/job_content/JC_Science/JSC_LifePhysicalandSocialScienceTechnicians/JOB_LaboratoryTechnician/jobzilla_html?jobprofiles=1)

Environmental chemist

"Environmental chemist" is a general term. This work may focus on collecting and analyzing samples, developing remediation programs, changing production processes to yield a more environmentally friendly product, providing expert advice on safety and emergency response, or dealing with government regulations and compliance issues.
(http://www.chemistry.org/portal/resources/?id=c373e9f5bf5914ed8f6a4fd8fe800100)
They must understand concepts of acids and bases, solutions, concentration, mixtures, and analysis of samples.

Industrial Safety and Health Engineers

An industrial safety and health engineer might have to do the following tasks:
- Devises and implements safety or industrial health program to prevent, correct, or control unsafe environmental conditions.

- Provides technical guidance to organizations regarding how to handle health-related problems, such as water and air pollution.
- Conducts plant or area surveys to determine safety levels for exposure to materials and conditions.
- Conducts or directs testing of air quality, noise, temperature, or radiation to verify compliance with health and safety regulations.
(http://www.xap.com/Career/careerdetail/career17-2111.01.html)
They must understand concepts of acids and bases, solutions, concentration, and mixtures.

C-6.1 Summarize the process by which solutes dissolve in solvents, the dynamic equilibrium that occurs in saturated solutions, and the effects of varying pressure and temperature on solubility.

Revised Taxonomy Level 2.4 <u>Summarize</u> conceptual knowledge

In physical science, students

- Distinguish chemical properties of matter (including reactivity) from physical properties of matter (including boiling point, freezing/melting point, density [with density calculations], solubility, viscosity, and conductivity). (PS-3.1)
  - *In reference to solubility*
    - Understand the term solubility only in terms of whether or not a substance will dissolve.
    - Be able to give examples of solids, liquids, and gasses that readily dissolve in water.
    - Understand the components of solutions (and therefore mixtures) do not chemically combine to form a new substance and therefore, solutions are composed of two substances which each retain their own properties. Therefore solubility is a physical property.
- Explain the effects of temperature, particle size, and agitation on the rate at which a solid dissolves in a liquid. (PS-3.5)

Note to teachers: In Physical Science, solubility is defined as a physical property because solutions are defined as homogeneous mixtures. However, as students study chemistry they will find that the dissolving process varies with the characteristics of the solute and the solvent respectively. The attraction of various solute particles to water molecules varies and if this force is strong, the dissolving process is considered a chemical reaction.

- **It is essential for students to**
- Distinguish between solutions, suspensions, and colloids on the basis of
  - Particle size
  - Settling behavior
  - Capacity to be separated by filtration
  - Capacity to scatter light (Tyndall Effect)
- Describe the formation of a liquid solution
  - Breaking up of the solute into individual components (expanding the solute)
  - Overcoming intermoleculear forces in the solvent to make room for the solute (expanding the solvent)
  - Interaction between the solvent and the solute to form the solution
- Explain solution equilibrium in terms of La Chatliers' Principle

- Distinguish among the following conditions
  - Saturated solution: a solution which contains the maximum amount of solute under the existing conditions (temperature, and volume of solvent)

        - ♦ Understand solubility as the amount of substance required to form a saturated solution with a specific amount of solvent at a specified temperature.
    - ➢ Unsaturated solution: a solution which contains less than the maximum amount of solute under the existing conditions (temperature, and volume of solvent)
    - ➢ Supersaturated solution: a solution that contains more dissolved solute than a saturated solution contains under the same conditions.
    - ➢ Understand the effect of pressure on the solubility of gasses in liquids.
- ❖ Distinguish among strong electrolytes, weak electrolytes, and nonelectrolytes
- ❖ Understand the effect of temperature on solubility of solids in liquids, gasses in liquids, and liquids in liquids

Assessment

The revised taxonomy verb, summarize means "to abstract a general theme or major point" For this indicator, the major focus of assessment should be to insure that students have a conceptual understanding of the terms and concepts associated with the process of solvation. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together. In this case, that students understand the interrelationships among the factors that effect the process of salvation.

C-6.2 Compare solubility of various substances in different solvents (including polar and nonpolar solvents and organic and inorganic substances).

Revised Taxonomy Level 2.6 <u>Compare</u> conceptual knowledge

Students did not study this concept in physical science

It is essential for students to

- Understand the observation that "like dissolves like"
  - compare polar and nonpolar solvents in terms of
    - Structure
    - Organic vs. inorganic substance
    - Common examples
- Predict conditions which favor solubility of a particular solute in a given solvent based on
  - The structure of the solvent
  - The structure of the solute
  - The temperature
  - The pressure
- Give examples of solutions composed of substances which exist in various phases at room temperature.
  - Gas dissolved in gas
  - Gas dissolved in liquid
  - Gas dissolved in solid
  - Liquid dissolved in liquid
  - Liquid dissolved in solid
  - Solid dissolved in solid

Assessment

As stated in the indicator, the major focus of assessment is to <u>compare</u> (detect correspondences) in the degree to which various solutes will dissolve in various solvents based on the factors which influence solubility. Because the indicator is written as <u>conceptual knowledge,</u> assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students understand not only the way that each factor affects solubility but also the reasons that each factor affect solubility.

C-6.3 Illustrate the colligative properties of solutions (including freezing point depression and boiling point elevation and their practical uses).

Revised Taxonomy Level 2.2-B Exemplify (illustrate) conceptual knowledge

Students did not study this concept in physical science

It is essential for students to

- Understand that colligitave properties are properties that depend on the concentration of solute particles but not on their identity.
- Describe melting point depression and boiling point elevation qualitatively in terms of Kinetic Molecular Theory
  - Explain how the concentration of the solution may differ from the concentration of the solute particles.
- Discuss causes of the differences between expected and experimentally observed colligative properties of electrolytic solutions.
- Identify practical uses for the colligative properties of solutions.

Assessment

The verb exemplify (illustrate) means to find a specific example or illustration of a concept or principle, therefore the major focus of assessment should be for students to give examples that show that they understand how the concentration of the solute particles in a solution affect colligative properties. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together. In this case, that students understand how the colligative properties of substances in solutions are affected by the number of solute particles in terms of the Kinetic Molecular Theory.

C-6.4 Carry out calculations to find the concentration of solutions in terms of molarity and percent weight (mass).

Revised Taxonomy Level 3.2 C_A Apply (carry out) procedural knowledge
Students did not study this concept in physical science

It is essential for students to

- Solve problems involving the Molarity of a solution (moles of solute per volume of solution) (moles/liter)
  - Molarity (M)
  - # moles of solute
  - Volume of solution
  - Mass of solute
- Determine the percent weight (mass) of a solution (mass of solute/mass of solution x 100) (%)

Assessment

The revised taxonomy verb for this indicator is implement (apply), the major focus of assessment should be for students to show that they can "apply a procedure to an unfamiliar task". The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods" In this case the procedure for quantitatively finding the concentration of a solution in terms of Molarity or percent weight. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat problems which are familiar. This requires that students have a conceptual understanding of Molarity and percent weight.

C-6.5 Summarize the properties of salts, acids, and bases.

Revised Taxonomy Level 2.4 <u>Summarize</u> conceptual knowledge

In physical science students

- **Classify various solutions as acids or bases according to their physical properties, chemical properties (including neutralization and reaction with metals), generalized formulas, and pH (using pH meters, pH paper, and litmus paper). (PS-3.8)**

It is essential that students

- Describe the properties of acids, including
  - The Arrhenius Definition of an acid as a molecular substance that ionizes, releasing hydrogen ions when it is mixed with water.
  - The reaction of acids with metals that are chemically active to produce hydrogen gas
  - The effect of acids on indicators
  - Neutralization of bases
  - Sour taste
  - Have a pH less than 7
- Describe the properties of bases, including
  - The Arrhenius Definition of a base as a substance whose water solution releases hydroxide ions as the only negative ions when it is mixed with water.
  - Bases are electrolytes
  - The effect of bases on indicators
  - Neutralization of acids
  - Water solutions of bases taste bitter and feel slippery
  - Have a pH greater than 7
- Describe the properties of salts, including
  - Salts are defined as ionic compounds containing a positive ion other then the hydrogen ion and a negative ion other than the hydroxide ion.
  - High melting points
  - Good conductors of electric current either when molten or when dissolved in water

Assessment

The revised taxonomy verb, summarize means "to abstract a general theme or major point" For this indicator, the major focus of assessment should be to insure that students can differentiate acids, bases and salts in terms of properties and structures. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together. In this case, that students understand how the composition of these species affect the way that they react and their physical properties.

C-6.6 Distinguish between strong and weak common acids and bases.

Revised Taxonomy Level 4.1B <u>Distinguish</u> conceptual knowledge

Students did not study this concept in physical science

It is essential for students to

- Understand the difference in the terms strong and concentrated and the difference in the terms weak and dilute
- Recognize and write ionization equations for the following five strong acids
  - HI
  - HBr
  - HCl
  - $HN0_3$
  - H_2SO_4
- Recognize and write ionization equations for the following four strong bases
  - $Ca(OH)_2$
  - $Ba(OH)_2$
  - KOH
  - NaOH
- Differentiate between Arrhenius, Brønsted-Lowry, and Lewis definitions of acids and bases
- Identify conjugate acid/base pairs in ionization reactions and relate the strength of acids and bases to relationship between conjugate acid/base pairs
  - Strong acids produce weak conjugate bases
  - Strong bases produce weak conjugate acids

Assessment

As the verb for this indicator is differentiate (distinguish), the major focus of assessment should be for students to distinguish between the relevant and irrelevant parts of presented materials. Because the verb is differentiate rather than compare, students should be able to not only identify strong and weak acids from a list but also compare the strength of acid/base pairs in ionization reactions.. Because the indicator is written as <u>conceptual knowledge,</u> assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together."

C-6.7 Represent common acids and bases by their names and formulas.

Revised Taxonomy Levels 2.1 B Represent (interpret) conceptual knowledge

Students did not study this concept in physical science

It is essential for students to

- Recognize and differentiate binary acids and oxyacids
- Recognize the names and formulas of common acids including
  - The strong acids listed in C-6.6
  - Acetic acid
  - Carbonic acid
  - Phosphoric acid
- Recognize the names and formulas of common bases including
  - The strong bases listed in C-6.6
  - Ammonia

Assessment

The verb interpret (represent) means that one major focus of assessment will be for students to "change from one form of representation to another", in this case, from the name of the acid or base to the molecular formula of the acid or base, or from the molecular formula to the name.

The following eight indicators (6.8 -6.15) should be selected as appropriate to a particular course for additional content and depth:

C-6.8 Use the hydronium or hydroxide ion concentration to determine the pH and pOH of aqueous solutions.

Revised Taxonomy Level 3.2 C_A Apply (use) procedural knowledge

Students did not study this concept in physical science

It is essential for students to

- Define pH and pOH and relate the definitions to the self-ionization of water
- Use logs and exponents to determine the pH or pOH of a substance from the concentration of the solution.
- Compare pH as determined by pH meters and indicator paper

Assessment
The revised taxonomy verb for this indicator is implement (use). The major focus of assessment will be for students to show that they can "apply a procedure to an unfamiliar task." The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods." In this case the procedure for calculating the pH and the pOH of a solution. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat problems which are familiar. This requires that students have a conceptual understanding of pH and pOH as they apply it to the concentration of hydrogen ions and hydroxide ions in a solution.

C-6.9 Explain how the use of a titration can determine the concentration of acid and base solutions

Revised Taxonomy Levels 2.7 B Explain conceptual knowledge

Students did not study this concept in physical science

It is essential for students to

- Write neutralization equations for the reaction between common selected strong acids and strong bases.
  - (See C-6.14)
- Explain the process of titration.
- Explain how indicators are used in titration
- Use data from the titration of a strong acid by a strong base to identify the equivalence point and the concentration of the acid.
- Analyze the titration curve of a strong acid/strong base reaction and compare the sensitivity of pH change to volume of titrant added

Assessment

The verb, explain means that the major focus of assessment should be for students to "construct a cause and effect model." In this case, assessments will ensure that students can show the effect that increasing quantities of a strong base have on the pH of a strong acid. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments should show that students can construct a cause and effect statement relating how the process of titration can show the equivalence point of the reaction and can therefore be used to determine the concentration of the acid (or the base)

C-6.10Interpret solubility curves to determine saturation at different temperatures.

Revised Taxonomy Levels 2.1 B Represent (interpret) conceptual knowledge

Students did not study this concept in physical science

It is essential for students to

- Compare the solubility curves of selected solids dissolved in water
  - Understand that the solubility of most solids is directly proportional to temperature, however the degree to which temperature affects the solubility of a solid varies with the structure of the solid
- Compare the solubility curves of gasses in water
  - Understand that the solubility of most gasses is inversely proportional to temperature, however the degree to which temperature affects the solubility of a solid varies with the structure of the solid

Assessment

The verb for this indicator is interpret (represent) the major focus of assessment will be for students to "change from one form of representation to another." In this case, the students should be able to describe the effect that temperature has on the solubility of solids and gasses from a graphical representation. As this indicator is classified as conceptual knowledge, it is vital that students can apply their knowledge of solubility to a solubility graph.

C-6.11 Use a variety of procedures for separating mixtures (including distillation, crystallization filtration, paper chromatography, and centrifuge).

Revised Taxonomy Level 3.2 C_A Apply (use) procedural knowledge

In physical science students

- Classify matter as a pure substance (either an element or a compound) or as a mixture (either homogeneous or heterogeneous) on the basis of its structure and/or composition. (PS-3.4)
  - Students must also understand that when matter is composed of two or more component substances which retain their own identifying properties, the matter is classified as a *mixture*.
    - A mixture can be separated physically because the components of the mixture have different physical properties. Mixtures do not have definite composition; the components of a mixture may be in any ratio.
    - Procedures for separating mixtures include: Dissolving, Filtering, Evaporating, Decanting, Magnetic separation, or Separating by particle size
    - Mixtures can be classified into two groups, heterogeneous and homogeneous.
      - *Heterogeneous mixtures* do not have the components distributed evenly throughout.
      - *Homogeneous mixtures* have components evenly distributed. The components are small that they can not be seen with the naked eye.
  - A *solution* is a homogeneous mixture in which the components are close to the size of individual particles of the substance (atoms, molecules, or ions) and therefore, too tiny to be seen with a microscope.(Ions will be addressed in PS-4.2)
  - Students should know that mixtures can occur among all phases of matter:
    - Gas/gas (air), Gas/liquid (oxygen in water), Liquid/liquid (alcohol in water), Liquid/solid (sugar in water), Solid/solid (alloy such as steel)

It is essential for students to

- Describe what types of mixtures are best suited for each separation process and give examples.
- Apply various process for separating mixtures of various substances
  - Describe the importance of each step in each of the above separation processes to the overall process.
- Understand how differentiation in the properties of the components of the mixture allow for each process

Assessment

The revised taxonomy verb for this indicator is implement (use), the major focus of assessment will be for students to show that they can "apply a procedure to an unfamiliar task". The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods" In this case various procedures for separating a mixture. Assessments should require that students show that they can apply the knowledge to a new situation, not just repeat the exact procedures which they

have studied. This requires that students have a conceptual understanding of each process.

C-6.12 Use solubility rules to write net ionic equations for precipitation reactions in aqueous solution.

Revised Taxonomy Level 3.2 C_A <u>Apply</u> (<u>use</u>) procedural knowledge

Students did not study this concept in physical science

It is essential for students to

- Understand and use a hierarchical list of solubility rules to predict whether a compound is soluble or insoluble in aqueous solution.
  - Most sodium, potassium, and ammonium compounds are soluble in water
  - Most nitrates, acetates, and chlorates are soluble.
  - Most chlorides are soluble, except those of silver, mercury (I), and lead. Lead (II) chloride is soluble in hot water.
  - Most sulfates are soluble, except those of barium, strontium, and lead.
  - Most carbonates, phosphates, and silicates are insoluble, except those of sodium, potassium, and ammonium.
  - Most sulfides are insoluble, except those of calcium, strontium, sodium, potassium, and ammonium.
- Predict the formation of a precipitate when aqueous solutions of two soluble ionic compounds are mixed.
  - Write the possible double-replacement reaction
    - $Zn(NO_3)_{2(aq)} + (NH_4)_2S_{(aq)} \longrightarrow ZnS_{(?)} + 2NH_4NO_{3(?)}$
  - Identify the precipitate
    - Zinc sulfide is not a soluble sulfide and is therefore a precipitate
    - Ammonium nitrate is soluble
  - Add the phase symbols to the products in the double replacement reaction
    - $Zn(NO_3)_{2(aq)} + (NH_4)_2S_{(aq)} \longrightarrow ZnS_{(s)} + 2NH_4NO_{3(aq)}$
  - Write the overall ionic equation
    - $Zn^{+2}_{(aq)} + 2(NO_3)^-_{(aq)} + 2(NH_4)^+_{(aq)} + S^{-2}_{(aq)} \longrightarrow ZnS_{(s)} + 2NH_4^+_{(aq)} + 2NO_3^-_{(aq)}$
  - Write the net ionic equation.
    - $Zn^{+2}_{(aq)} + S^{-2}_{(aq)} \longrightarrow ZnS_{(s)}$

Assessment

The revised taxonomy verb for this indicator is <u>implement</u> (<u>use</u>), the major focus of assessment will be for students to show that they can "apply a procedure to an unfamiliar task". The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods" In this case the procedure for using a solubility table and the procedure for writing a net ionic equation. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat problems which are familiar. This requires that students have a conceptual understanding the solubility rules and the process for writing net ionic equations.

C-6.13Use the calculated molality of a solution to calculate the freezing point depression and the boiling point elevation of a solution.

Revised Taxonomy Level 3.2 C_A <u>Apply</u> (<u>use</u>) procedural knowledge

Students did not study this concept in physical science

It is essential for students to

- Calculate the concentration on a solution in terms of molality (m)
  - moles of <u>solute</u> per mass of <u>solvent</u>
  - moles/kg
- Calculate the freezing point depression of a nonelectrolyte solution using the equation:
  - The change in freezing point (Δt_f) of a solution is equal to the molal freezing point constant (K_f) times the molality of the solution (m).
  - ($\Delta t_f = K_f m$)
- Calculate the boiling point elevation of a nonelectrolyte solution using the equation:
  - The change in boiling point (Δt_b) of a solution is equal to the molal boiling point constant (K_b) times the molality of the solution (m).
  - ($\Delta t_b = K_b m$)
- Understand that the boiling point elevation or melting point depression of an electrolyte is dependent upon the number of moles of particles in the solution.
- Calculate the melting point elevation or boiling point depression of electrolytes
  - Determine the number of moles of particles in solution per moles of solute (molality coversion)
    - $(NH_4)_2S_{(aq)} \longrightarrow 2NH_4^+{}_{(aq)} + S^{-2}{}_{(aq)}$
    - 1mole $\longrightarrow$ 3 moles
    - molality conversion is 3moles/1mole
  - ($\Delta t_f = K_f m$ x molality conversion)
  - ($\Delta t_b = K_b m$ x molality conversion)
- Understand that the predicted value for both freezing point depression and boiling point elevation will be greater than the actual values due to deviation of real solution behavior from ideal solution behavior.

Assessment

The revised taxonomy verb for this indicator is <u>implement</u> <u>(use)</u>, the major focus of assessment will be for students to show that they can "apply a procedure to an unfamiliar task". The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods" In this case the procedure for determining the freezing point depression or boiling point elevation of both nonelectrolytic and electrolytic solutions. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat problems which are familiar. This requires that students have a conceptual understanding of colligative.

C-6.14 Represent neutralization reactions and reactions between common acids and metals by using chemical equations.

Revised Taxonomy Levels 2.1 B Represent (interpret) conceptual knowledge

In physical science students

- Classify various solutions as acids or bases according to their physical properties, chemical properties (including neutralization and reaction with metals), generalized formulas, and pH (using pH meters, pH paper, and litmus paper). (PS-3.8)

It is essential for students to

- Use an "Activity Series Metals" table to predict whether a metal will replace hydrogen in a given reaction.

More Active

Less Active

Activity Series	
Metals	
Li	React with cold water and acids replacing hydrogen
Rb	
K	
Ba	
Sr	
Ca	
Na	
Mg	React with steam (but do not react with cold water) and acids replacing hydrogen.
Al	
Mn	
Zn	
Cr	
Fe	
Cd	
Co	Do not react with water. React with acids, replacing hydrogen
Ni	
Sn	
Pb	
hydrogen	
Sb	Do not replace hydrogen in water or in acids
Bi	
Cu	
Hg	
Ag	
Pt	
Au	

- Write balanced equations for the reactions between common acids and metals.
- Understand that neutralization of a strong acid and a strong base occurs when the concentration of hydrogen ions [H^+] and hydroxide ions [OH^-] are each at 1 x 10^{-7}M in the solution.
- Use stoichiometry and titration calculations to predict whether various ratios of acid concentration and volume to base concentration and volume will result in a neutral solution.
- Write balanced equations for the neutralization reactions between selected common strong acids and strong bases.

Assessment

The verb interpret (represent) means that one major focus of assessment will be for students to "change from one form of representation to another", in this case, to represent chemical reactions between metals and acids and between strong acids and strong bases with chemical formulas. As this indicator is classified as conceptual knowledge, it is vital that students can apply their knowledge of the chemical reactions of acids and their understanding of chemical equations to represent any given reaction which follows the pattern represented here.

C-6.15 Analyze the composition of a chemical sample by using gas chromatography.

Revised Taxonomy Level 4 <u>Analyze</u> conceptual knowledge

Students did not study this concept in physical science

It is essential for students to

- Understand that chromatography is the process of separating small amounts of substances from a mixture by the rates at which they move through or along a medium (the stationary phase). The components move at different rates because they vary in solubility and their attraction to the medium.
- There are several types of chromatography
  - Paper chromatography
    - The mixture is dissolved in a solvent and the medium through which the mixture moves is a piece of blotter paper.
  - Column chromatography
    - The mixture is placed in a column containing a material which attracts the molecules of the mixture.
  - Gas chromatography
    - The mixture is vaporized and passed along a heated column in a stream of gas.
- Describe what types of mixtures are best suited for separation by gas chromatography and give examples.
- Describe the importance of each step in the separation processes to the overall process.
- Understand how differentiation in the properties of the components of the mixture allow for separation by gas chromatography

Assessment

The revised taxonomy verb for this indicator is analyze which means to "break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose". In this case, students will use the process of gas chromatography to separate a mixture into component parts. Because the indicator is written as <u>conceptual knowledge,</u> assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to The verb <u>implement</u> <u>(use)</u> means that an additional focus of assessment will be for students to show that they can "apply a procedure to an unfamiliar task". The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods" In this case the gas chromatography procedure for separating a mixture. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat the exact procedures which they have studied. This requires that students have a conceptual understanding of mixtures and separation by chromatography.